

# RAS 2020 Robotics and Autonomous Systems

A national strategy to capture value in a cross-sector UK RAS innovation pipeline through co-ordinated development of assets, challenges, clusters and skills / July 2014

Special  
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Group

Robotics and  
Autonomous Systems



# RAS 2020

## Robotics and Autonomous Systems

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# Foreword

We live in an era of unprecedented change: to our businesses, our economies and our societies. Technological advancement has become a key driver of this change. Nations and industries that participate and lead will shape the next wave and enjoy improved international competitiveness, productivity and economic growth. A recent report by McKinsey estimated that the application of advanced robotics could generate a potential economic impact of \$1.9 trillion to \$6.4 trillion per year by 2025. This impact would result from improved health, new products and transforming the way in which products are built and services are delivered.

Responding to this internationally recognised opportunity, Robotics and Autonomous Systems (RAS) was identified by the UK Government in 2012 as one of the Eight Great Technologies that support the UK Industrial Strategy driving efforts to rebalance the UK economy and creating jobs and growth.

The UK has a significant store of RAS talent in its research community, small businesses and large corporations. When combined with the right investment, this ecosystem can build and feed an innovation pipeline that will realise new RAS products, services and businesses.

Following a series of round table events in 2012 involving key stakeholders from government, industry and academia, the Technology Strategy Board created the Robotics and Autonomous Systems Special Interest Group (RAS-SIG) in 2013. Under the leadership of a steering group, its mission was to understand the nature of the landscape and the opportunity for RAS in the UK, to connect fragmented communities of researchers, industrialists and civil servants and to produce a national strategy to align our efforts and inform future Government resourcing and organisation.

During 2013-14 the RAS-SIG led a series of community activities to build networks, roadmap sectors, establish capabilities, investigate market opportunities and value chains, understand regulatory environments, and inform the public. From this, the RAS-SIG steering group has identified five interwoven strands of activity as the core focus for UK investment and action going forward. In these we aim to kick-start and stimulate innovation by capturing the interest and the enthusiasm of the public, investors, researchers, engineers and businesses in showcasing disruptive developments with potential. Initial Government support will enable the sector to reach a tipping point at which private investment and the market take over.

We believe the UK has the potential to be a world-leading nation in the race to create a new generation of smarter tools and services that we will use in our homes and workplaces. Moreover, we believe we understand what we have to do to create innovation from our inventions and attract talent to the UK. There are clear steps the UK can take to turn its potential in this area into significant economic growth and societal benefits.

This strategy is the result.

**David Lane FEng, Rob Buckingham FEng** RAS-SIG Steering Group Chair and Co-Chair July 2014

## Recommendations

### The strategy recommends the following:

1. Invest further in the five RAS strategy strands: coordination, assets, challenges, clusters and skills to build the UK's RAS capability.
2. Establish the means for funding agencies to formally work together in execution, so that ideas, people and activity flow readily from basic investigation through early stage demonstration to fully trialed commercial product.
3. Establish a RAS Leadership Council to engage with senior leaders across a range of sectors in industry, academia and Government, providing independent advisory oversight of planning and execution of the strategy.
4. Further develop engagement with the EU, investors and corporate resources in the UK and overseas to fuel the development of the 5 strands.
5. Continue to consult widely on potential Assets and cross sector Grand Challenges.
6. Continue to develop dialogue with those involved in standards and regulation, such as BSI and CAA, to develop more detailed thinking.
7. Extend outreach and public engagement activities to continue changing public perceptions and improve understanding of public concerns.
8. Articulate to businesses and investors internationally (e.g. through UKTI) that the UK aims to be the best place to invest in taking RAS technologies to market.

# Executive Summary

Robotics and Autonomous Systems are one of the Eight Great Technologies identified by the UK Government as a key area with the potential to drive the industrial strategy for economic growth.

## **OUR VISION** *New and smarter tools for a new millennium*

Beyond automation and control, Robotic and Autonomous Systems (RAS) are interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. They perform useful tasks for us in the real world, extending our capabilities, increasing our productivity and reducing our risks.

In the future, we will increasingly use RAS to enhance almost every aspect of our lives. They will be part of our response to national challenges: an ageing population, safer transport, efficient healthcare, productive manufacturing, and secure energy. RAS technologies will be truly transformational for the whole of society, part of the 'Embodied Internet' that will be at the heart of our future smart cities, smart homes and smart industries.

Acting as the arms and legs of 'Big Data', connected in 'The Internet of Things', RAS is a ubiquitous and underpinning technology that can fuel the UK's Industrial Strategy. There are clearly identifiable hot spots where RAS capability can impact on vertical sectors including aerospace, agriculture, automotive, energy, health, manufacturing, marine, nuclear and transport. These can be used to inform public and private investment decisions.

Our vision is to reinforce a RAS ecosystem in the UK that will develop skills and allow ideas and innovation to be created and tested in the market place, ahead of international competitors. Technological innovations must be demonstrated in real world environments because RAS tools will be expected to work reliably and efficiently in these places. Addressing this will also involve shaping key regulatory and standards issues, so that success attracts private and inward investment at a tipping point when public investment is no longer needed.

Through a co-ordinated approach and targeted investment, the UK can become an internationally leading nation in capturing the value from our invention into our innovation.

## **SEIZING THE MOMENT TO TAKE ACTION** *Playing as a team for competitive advantage*

The UK is uniquely positioned to take significant advantage from an aligned and market oriented approach to RAS that builds upon the strengths and resources within the UK economy. While many governments (notably USA, Korea, China, Japan, Germany and France) have recognised the strategic role of RAS in their future economies, the resulting support programmes have been largely sector-specific or technology-focused.

By acting soon, decisively and in concert, we have the opportunity to capture the early mover advantage and establish the UK as a leader in the implementation of RAS technology. This will be achieved by developing a market-focussed approach, building sustainable value chains that will support the introduction of RAS technologies into multiple new markets while also invigorating existing markets with disruptive and economically advantageous products. Such an approach will build on UK strengths in the fields of ICT, big data and systems engineering as well as UK specific market opportunities in areas such as energy, legacy decommissioning and healthcare. Public intervention will be particularly useful in areas such as RAS-appropriate legislation and standards as well as the use of public assets to assist the transition of new products into viable commercial companies. In particular, a joined-up RAS strategy will help build an effective RAS ecosystem including skills, finance, research, innovation and regulation and including both demand and supply chain components.

The UK must also capitalise on its participation in the EC's robotics research and innovation programme, currently the largest civilian robotics programme on the planet (£1.6 billion over 7 years with £560 million being directly funded by the European Commission). By a careful mix of influence, alignment and differentiation the UK stands to gain a major boost that can amplify the effects of a coordinated RAS strategy.

## **STRATEGIC APPROACH** *Five interwoven strands to build a RAS ecosystem*

The focus of the UK approach is to develop and demonstrate RAS technologies in real situations. At its heart, the strategy sets out to identify and invest in real world tangible RAS Assets which are collaborative proving grounds. These will be used to host a series of RAS Grand Challenge competitions in different sectors and applications. The intention is to expose RAS technology to the rigours of real environments; to identify technical strengths and weaknesses, and to explore commercial opportunities. Where appropriate these assets and associated challenges will span sectors, encouraging increased awareness of different approaches and solutions to generic problems. This will also have the effect of increasing early stage market size, which is critical to allow SMEs to scale.

To achieve this vision five interwoven strategic strands have been identified:

## RAS COORDINATION

Aligning the instruments of investment in research, business and regulation so that UK efforts form a cohesive, coherent innovation pipeline, shaping a common and competitive approach in different sectors.

## RAS ASSETS

Developing tangible and intangible assets from demonstration sites in farms, factories, oil and gas plants, nuclear facilities, roads, airports, homes and hospitals, to a flexible legal and regulatory environment, pervasive software skills and a willingness to try new ideas. These will make UK the RAS destination of choice for international research, innovation and market exploration.

## RAS GRAND CHALLENGES

Focusing competitions on real scenarios in vertical markets that “stimulate collaboration, identify the possibilities, and excite the public”. Using the RAS Assets as staging grounds for a series of Grand Challenges will widen engagement and establish regulation ahead of the market.

## RAS CLUSTERS

Investing in locations to stimulate cross fertilisation and linkage between elements of the RAS supply chain. These clusters will bring together industry, academia, finance and innovators into ecosystems creating a gearing effect for success and establishing an innovation pipeline.

## RAS SKILLS

Developing the skills base and explaining the benefits of RAS technology is an inherent and essential part of achieving success. Implementation of this strategy requires a breadth of engagement between industry, academia, government and the investment community to capture the vision, enthusiasm and proposals that are essential to create a RAS industry in the UK.

### RAS in Action

## Aerospace

The UK has a 17% share of the global aerospace market, making it the largest in Europe and second only to the US worldwide.

The aerospace sector generates £24 billion per annum for the UK sustaining over 100,000 direct jobs. It is estimated that over the next 20 years civil air traffic will grow at 4.7% annually, requiring over 29,220 new passenger aircraft and freighters at a value of nearly

£2,900 billion. Robotic and Autonomous Systems will increasingly become a discriminator in the market, enabling aerospace robotic systems to safely and routinely perform tasks that are “dull, dirty and / or dangerous”. Investment in this area will simultaneously create quality jobs in the UK and open up export markets for unmanned aircraft systems (UAS) and related services. It will protect UK industry from its disruptive effects and open the way to the migration of innovative UAS technology (such as collision detect and avoid), once proven on unmanned aircraft, to manned aircraft thus improving flight safety for all.

UAS are already making great strides in civilian markets. Amazon is developing and testing a small unmanned rotorcraft to deliver small parcels to customers. Google has purchased Titan Aerospace, to provide wide area wireless network connectivity in regions of the world not yet served with a reliable communications infrastructure.

The development of collision detect and avoid systems for use on unmanned aircraft of all sizes is top priority in this area. Autonomy is critical, since the unmanned aircraft would typically need to decide for itself on the action to take to avoid a collision and on the subsequent action to safely continue its journey. There is an opportunity for the UK to leverage this autonomous aerospace robotics technology in the form of increased export sales of unmanned aircraft systems and related services to organisations in oil and mineral rich countries with both a means to pay for this capability and an interest in the value of the information it provides. This “winner takes all” opportunity is expected to materialise over the next 5 years.



# 1.0 The Importance of RAS

## The next generation of smarter tools

Beyond automation and control, Robotic and Autonomous Systems (RAS) are interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. They perform useful tasks for us in the real world, extending our capabilities, increasing our productivity and reducing our risks.

Developing and operating new tools is essential for tasks in harsh environments, where people should not or cannot go. However wider opportunities for RAS exist, from enabling a better quality of life for the elderly to more efficient transport and farming. Collaborative systems are in development that work alongside us to improve efficiency and safety in factories and workplaces and enhance our movement and physical capability.

Extending our cognitive reach has even wider application, allowing the creation of intelligent co-workers as companions and tools that work with us and for us without constant direction. The ability of RAS to extend our physical and cognitive functions creates a significant opportunity for impact in many industrial sectors.

Success will include unforeseeable opportunities. As we fashion these new tools we will change ourselves and our future.

The potential array of RAS applications suggests that RAS technology will take many forms. Some may be embedded in familiar objects such as cars whilst others will look strikingly new.

### A RAS tool will have:

- sensors that collect data from the immediate environment
- the ability to move, both itself and other things
- software to process information, to mediate between sensory inputs, to control motion, to plan actions and to interface with people.

Core across all forms is the need for a RAS tool to 'interact'. This takes many forms including interaction and adaption to the local environment, interconnection with other RAS devices to share information as part of smart systems, the interaction of people with RAS devices, and self-interaction to monitor internal health and correct operation. For example, an autonomous car will interact and synchronise with the vehicles around it, maintaining safety and optimising its journey. It will sense its environment and decide how to act from one millisecond to the next. It will also interact with the humans inside, for navigation direction and safe operation. Designs incorporating RAS are already creating their own forms, reshaping our future cities, roads and factories.

## RAS in Action

### Offshore Energy

49% of the UK's primary energy demand is satisfied by oil and gas from the North Sea continental shelf.

This natural resource further contributes £40 billion to the UK, with the supply chain adding a further £6 billion in exports of goods and services. The industry is vital to the economy, supporting 440,000 jobs across the country with 24 billion barrels remaining compared to 41 billion recovered so far. Autonomous marine robots represent a disruptive technology for inspection and survey of subsea infrastructure, and are poised to revolutionise the value chain in favour of UK industry. Further investment would see robots equipped with manipulators playing a more active role in maintenance, allowing them to autonomously address interventions and make necessary repairs.

Government funding would finance the construction of an underwater robotics testbed on an existing site, stimulating innovation in Subsea Inspection Repair Maintenance as well as multi-vehicle aircraft black box search and recovery.



## Nuclear Robotics

The UK's Nuclear Future Strategy has identified that a nuclear industry renaissance over the coming decades will see around £930 billion invested globally in new build fission reactors, an estimated global plant life extension (PLEX) worth £39.4 billion for the period of 2012-2020 alone.

Although nuclear energy is currently responsible for around 20% of the UK's total supply, this figure is expected to rise to nearer 50% by 2030. In order to achieve the required 16GW of new nuclear power, £60 billion is being invested into a build of 12 new reactors at five sites across the UK. Hinkley Point, a £12 billion project to be constructed and operated by EDF Energy, will be the first nuclear power station built in the UK since 1995.



An inevitable byproduct of the rise of nuclear energy is the creation of a global decommissioning market, currently estimated to be worth £50 billion per annum by 2020. The total cost of nuclear decommissioning in the UK alone, mostly at Sellafield, is currently estimated at £60 billion. Analysis by the National Nuclear Laboratory indicates that 20% of the cost of complex decommissioning will be spent on RAS technology.

Owing to the high levels of radiation, all stages of the nuclear fission and fusion life cycle will require the use of advanced RAS tools and techniques. The need for innovation in this field turns the UK's existing nuclear infrastructure into a highly significant asset, allowing for extensive on-site testing under real-world conditions to de-risk new technology and develop the essential safety cases. The UK is well placed to seize this market with its strength in national laboratories and the supply chain.

The various vaults, ponds and other facilities at Sellafield; research reactors at Winfrith; the JET and MAST fusion experiments at the UKAEA, Culham; and EDF's reactor fleet, make us ideally placed to pioneer the next generation of tools and processes for nuclear remote operations. As the body of knowledge grows, the pace of safe, cost-efficient intervention will accelerate.

Knowledge and experience gained will be directly relevant to other challenging environments including submarine reactor systems and more widely in above ground infrastructure in the energy and construction sectors. Examples include petrochemical facilities, wind turbines and mining.

### DEGREES OF AUTONOMY FOR DIVERSE SITUATIONS

As human beings we are aware of our environment and can have long-term objectives. Our senses are adapted to collecting the information that we need to physically interact with our dynamic surroundings. We make complex decisions. We take calculated risks and even leaps of faith and imagination in order to achieve our aims. In comparison, the human-made devices we are describing are just the next generation of smarter machines. These devices will not function with human capabilities but will be able to act 'intelligently' within bounds. Autonomous operation will be a feature of most of these systems.

Autonomy is the ability to make decisions based on external events and internal goals that lead to different courses of action, even when faced with unexpected events and unknown environments. So an autonomous car will react accordingly to prevailing weather and traffic conditions. This ability broadens the usefulness of the machine and extends the period of time it can operate without human intervention.

Some RAS systems will be autonomous for long periods: for instance a robot to map the ocean floor or to explore Space. Most devices will be autonomous for much shorter periods, being given instructions by people through highly intuitive or transparent interfaces that will include direct physical interaction, voice, gesture, mood and context recognition. Constant exchange of decision-making authority, from human to computer software and back, will need to be natural and dependable.

### ESTABLISHING RAS STANDARDS AND REGULATIONS

Autonomous systems also require subtle adjustments to our laws, regulations and standards. Creating the best regulatory environment is key in attracting and creating RAS based products and services to the UK, with safe operations and the right regime to test and de-risk during development.

Discussions with market regulators and the UK Government show that the UK has the will and flexibility to explore these issues in a pragmatic manner. Demonstrating benefit will be an essential component of delivering innovation, especially where new risks are not directly comparable with current practices.

## CAPTURING THE IMAGINATION OF A NEW GENERATION

We see the arrival of RAS technologies as the inevitable extension of the digital internet. Whilst this is a positive development, RAS technologies will raise concerns – some legitimate, some very far-fetched. Of course, films and novels have explored some of these issues, and there is potential for RAS technology to be used for both good and bad. History shows that, in the medium and long term, new tools used by creative people have delivered a higher standard of living. The UK must position itself as a creator and user of these new tools.

There will be many reasonable and appropriate questions for public debate. As a progressive democracy with strong legal and regulatory frameworks that protect the public, and a flexible insurance industry that helps manage new risks, we should be at the forefront of RAS development to explore and shape the use of this exciting technology. The science and engineering community need to broaden awareness and understanding by, for instance, a campaign of business to business and public engagement.

According to a 2014 MORI report into Public Attitudes to Science, the overall attitude to RAS in the UK was found to be very much in line with those of other European countries. As is to be expected from the balance of media coverage, awareness of RAS usage was strongly skewed towards the manufacturing, space exploration and military or security sectors, with 24%, 22% and 16% respectively saying they had heard or read a great deal about these uses.

By contrast, the majority of the public said they had not heard anything about the use of robots in the care or education sectors. These results also show that general opposition to use of robots in specific sectors does not necessarily stop people from supporting certain specific applications.. People often find it difficult to envisage the potential uses of robots until they are presented with specific examples, such as improved prosthetic hands, or on demand parcel delivery. Greater awareness of the multiplicity of roles RAS are capable of performing can therefore lead to an increase in support from the general public.

For economic success, we must encourage a higher percentage of our brightest and best individuals to engage with STEM subjects. By embracing RAS technology in a responsible and open manner, we have the opportunity to use the fascination with robots to stimulate interest in STEM subjects and develop the skills base for a knowledge-driven economy.

### RAS in Action

## Intelligent Mobility

The primary road network in the UK is already working close to its limits of capacity.

Projected increases in population and other socio-economic factors suggest that demand for mobility will increase by more than 25% over the next two decades. Given that more than 90% of our current mobility demand is delivered through road transport, the nation will grind to a halt if this problem is left unattended.

Other countries have already begun testing cars that can drive themselves, interacting safely with other road users and using roads efficiently, thus freeing up precious time. The UK is off to a fantastic start in this area, with the Transport Systems Catapult, TRL, MIRA and the Oxford RobotCar, as well as the LUTZ project underway to install low-speed autonomous pods in Milton Keynes within 3 years.

To hasten this future and anchor it permanently to the UK we need large-scale realistic testing facilities, urban laboratories and private roads where innovative modes of transport can be trialed and perfected.

The economic benefit in terms of national costs avoided thanks to the use of RAS in transportation over the next 20 years is estimated to be in the order of £1tn.



## 2.0 RAS Markets and Opportunities

### A myriad of opportunities in a world of economic disruption

A recent McKinsey study into disruptive technologies estimates that by 2025 RAS technologies will have an impact on global markets of between \$1.9 and \$6.4 trillion per annum. Current estimates from Europe and Japan indicate that the market for RAS products and technology, for non-military sectors, will be in the order of £70 billion by 2020-2025.

Analysis of the UK GVA yields an estimate that RAS will have a high level of effect on some 15% of GVA amounting to £218 billion and a lower level on more than half of the sectors in the economy.

One pan-national survey of industrial robot usage estimated that if the UK optimised its current RAS technology it would raise productivity in manufacturing by up to 22%, with a long term employment increase of up to 7%.

General consensus therefore confirms that RAS technologies will enable new products, services and even business models in ways that have yet to be envisaged. New businesses and new business thinking will be essential to capture value as markets disrupt and change.

#### **Analysis of trends, opinions and historical precedent has confirmed that:**

RAS will have a significant impact on all sectors within the UK economy. It will increase business competitiveness, provide effective solutions to societal problems and give greater freedom and choice to individuals.

- RAS offers the potential to reduce government expenditure in critical areas such as security, healthcare and the management and decommissioning of infrastructure.
- RAS will impact on socio-economic challenges; the ageing society, food security, energy supply, transport and the decommissioning of infrastructure.
- RAS potential is already attracting investment by governments and private corporations in isolated and uncoordinated pockets.
- RAS will impact on competitiveness and productivity in the UK and, when applied in manufacturing to date, has resulted in a net gain in jobs over time.
- RAS enables the societal benefits of technology to be delivered to the public at large through public services such as the NHS and through private providers.
- The full benefits that RAS can bring are still emerging. Only through deploying RAS in the market will these innovative solutions and novel business models present themselves.
- Even in sectors where RAS represents an incremental development there will be novel and interesting avenues that will surprise us in the coming decades.

RAS will impact differently in each market sector it affects. It will enhance competitiveness. It will enable higher levels of service delivery and new services. Where it impacts on socio-economic challenges in novel ways, RAS technology will open a new landscape of opportunity to enhance lives or maximise the utilisation of limited resource. For example: In manufacturing the potential to reshore production is of key economic benefit. Not only creating jobs in the UK but also allowing manufacturers, particularly SMEs, to be more agile and responsive to the market. Cost-effective and flexible local production will transform the economics of cities and fundamentally change city infrastructures.

In the agri-food sector the potential for raising yields, increasing shelf life, traceability and minimising waste and energy use are key drivers. Value will be added through data gathered during farming and processing, allowing reduced pesticide and fertiliser usage and reduced environmental impact.

In health and social care collaborative robotics can offer assistance to nurses and staff providing physical lifting capability, automatic cleaning of equipment and improved rehabilitation outcomes. They will enable logistics services that allow staff to concentrate on care.

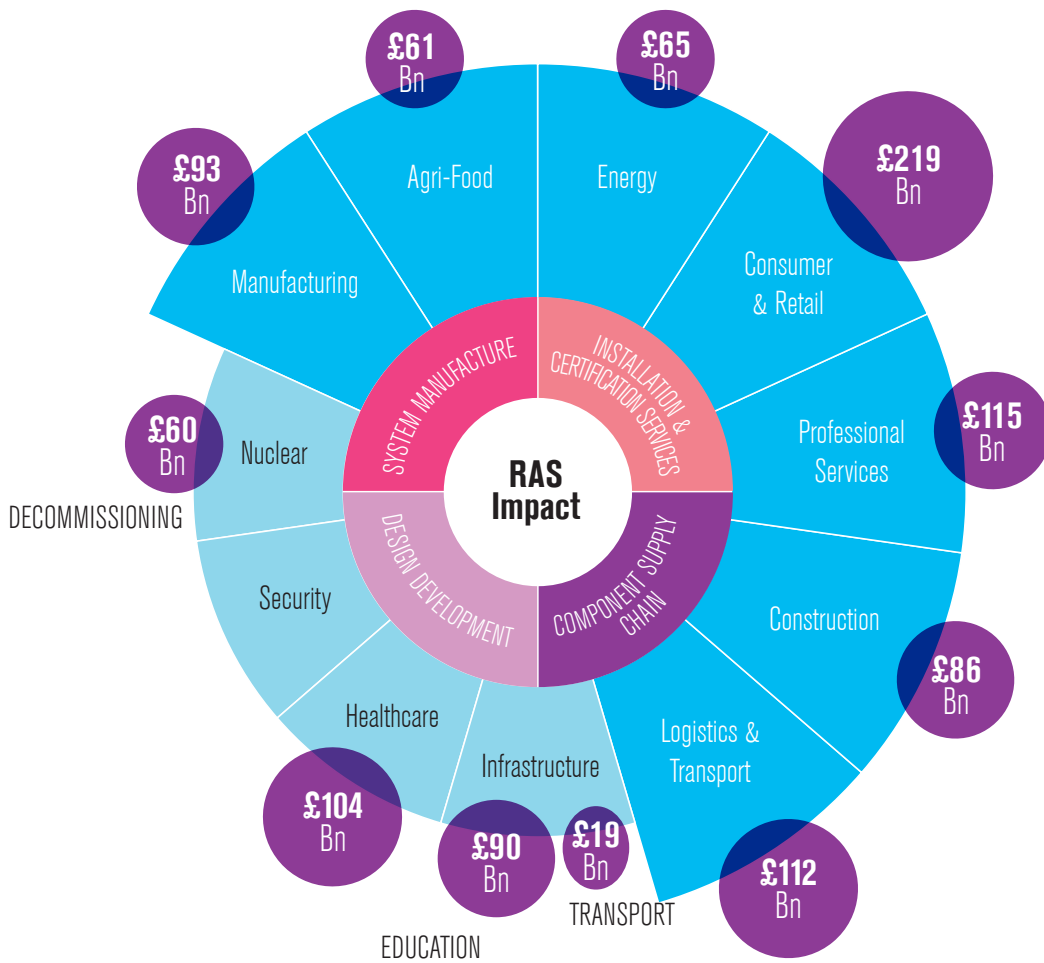
In logistics and transport the potential to provide more efficient services, on demand delivery and integrated transport are only a few of the longer term benefits that the application of RAS will bring.

In offshore energy RAS will reduce the cost of inspection, repair and maintenance of subsea infrastructure, while improving data quality and opportunistic access. The result is safer operations, reduced environmental risk and improved production.

Realising the projected economic impacts requires widespread adoption of RAS. The exact impact on each sector will depend on matching market need in terms of technology, function and cost. The adoption of RAS will occur only where there is an advantage. For this reason its application will vary between sectors. Flexibility will be an important asset, and it is only by starting to work in each sector that we will come to understand opportunities and the modes of adoption that market sectors prefer.

Regulation and certification will also be a vital part of RAS deployment in many sectors. RAS will operate in hazardous environments and in situations where people are vulnerable and at risk, in care homes, in hospitals, in operating theatres, in mines, under the sea, in the air, in nuclear power stations and in disaster zones. In all of these application areas safe operation is critical.

Fig 1: represents the market sizes affected or disrupted by the introduction of new RAS products and services. The larger sectors in dark blue represent those market sectors where RAS will have an impact, whereas the smaller sectors in light blue represent areas where government expenditure will be impacted by RAS.



## RAS in Action

# Farms of the Future

The growing global population presents severe challenges for future food security.

Integrating RAS into the farm offers outstanding opportunities for more effective energy use, radical reductions in treatment with fertiliser and pesticide, more effective use of land, reduced environmental impact and enhanced cropping systems, with attendant beneficial economic impact upon yields and quality through reducing the time from field to supermarket shelf.



RAS has already impacted on milk production allowing the farm to adapt to the herd rather than the herd to the farm. These radical changes have increased animal health and milk yield while providing an early warning of health issues and disease. Farmers have benefited from a less rigid schedule and greater herd knowledge.

Central to the robotic solution will be smarter, smaller machines that facilitate precision farming and offering a radical and revolutionary foundation for new developments that offer both economic advantage and beneficial impact upon the food security challenge.

In the absence of significant investment in this sector, anywhere in the world, the UK has the opportunity to take the lead in developing and promoting this technology, and sustain that lead by investment in a UK-based robotic research farm.

With sufficient investment to realise commercial systems the market could reach \$1 billion.

## 3.0 Building on Strong Foundations

### Growth and value capture beats subsidy from Government

The Government has raised the profile of technology innovation with enhanced funding, the identification of the Eight Great Technologies, and with the formation of the Catapults. The Technology Strategy Board (TSB), the UK's innovation agency, is engaged with enabling the middle stages of the innovation cycle, providing support to companies bringing novel products to markets. The Research Councils and universities ensure that the innovation pipeline is well fed via early stage research and development. The formation of a single Knowledge Transfer Network (KTN) also strengthens the innovation pipeline within the UK. The Royal Academy of Engineering provides an independent voice, and supports innovation directly through its Enterprise Hub.

Recent RCUK and TSB grants, along with private funding, have already input approximately £150M into businesses research, training and fellowships of direct relevance to robotics and autonomous systems, including recent capital awards, Centres for Doctoral Training and Small Business Research Initiatives. Further UK RAS investment is now needed along a number of fronts (Skills, Innovation, Capital and Research) to ensure the capability within the UK is strengthened, keeps pace with international investments and ensures the UK remains at the forefront of this rapidly expanding domain.

The UK has a diverse and established set of instruments to support and implement the five RAS strategic themes through these agencies, working closely and in combination (fig 3). The key is to use these instruments to support innovation up to the tipping point where corporate and/or other investor support seizes an opportunity, rendering public support unnecessary.

For success, a variety of funding instruments, including some only recently envisaged (Arrow projects) with agencies working closely and in concert are essential.

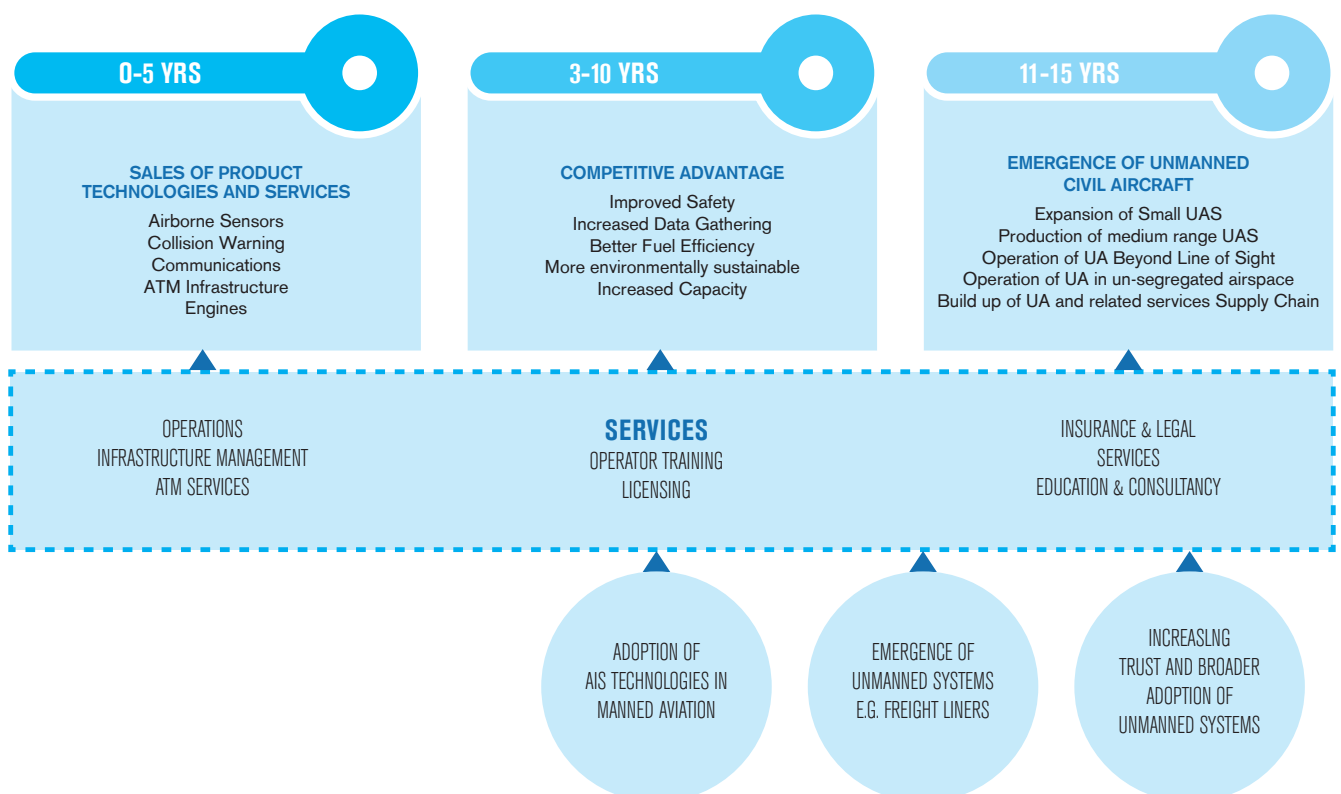


Fig 2 suggests a typical adoption life-cycle, featuring commercial transition to autonomous unmanned civil aircraft.

The UK contains a diverse RAS community. The major UK industrial strengths are echoed in its capability, from automotive to aerospace and medical to military. Within the UK there is extensive expertise in both autonomous aerial vehicles and unmanned maritime systems, in the application of RAS technology to a wide range of healthcare tasks, from surgery and rehabilitation and to assisted living. In the Oil and Gas industry there is considerable expertise in under water vehicles and autonomous operations. The UK also has hotspots of activity in ocean surveying, autonomous cars, social interaction, medical, agriculture, high value manufacturing and logistics.

There are numerous RAS based SMEs, some of which have strong international profiles working in a variety of sectors across the RAS landscape. In the right environment these will grow into strong mid-sized companies able to form the backbone of a strong value chain. This range of enterprise is strengthened by the extensive world-class software industry in the UK that covers all necessary applications from systems engineering to cognition and human robot interaction. This expertise is backed up by world-class universities that provide expertise in core RAS technologies such as perception, interaction and cognition.

There is also a strong user centric design ethic that has been exported globally with many global brands employing top UK product designers. This will be an essential element in RAS because of the interactive nature of many applications.

The UK therefore possesses the basic ingredients to create a powerful and effective RAS economy, but it requires coordination, access to assets as well as funding, and a supportive regulatory and innovation framework to flourish and bring products through the innovation pipe to market.

## RAS in Action

# Space

The space industry contributes over £9billion to the UK economy and aims to grow this to £40billion by the 2030's.

With no opportunity to repair, the space industry depends on reliable autonomous and robotic systems that work in extreme environments using the minimum amount of power. There are many areas where RAS will benefit the space industry from the production and operation of spacecraft and the utilisation of the data enabling growth. Challenging space science missions develop advance technology which can then be applied to terrestrial problems. For example, technology developed for Mars rovers is now being applied to the water industry, nuclear sector and could equally be applied to mining and agriculture. The facilities developed to test rovers, validate and verify autonomous systems could be used by the wider research community. The development of applications using space data is identified by the OECD as a major area of growth and might well be in support of RAS.

Looking to the future, RAS will be required to construct large platforms in space and on the moon and to assist astronauts with tasks or act as companions on long duration flights.



# Smart Cities

The global smart cities industry is estimated to be worth more than £230 billion by 2020.



Smart Cities integrate the digital and the physical, a natural place for RAS to play and grow.

RAS devices will become the actors in the system of systems making Smart Cities integrated and smooth running; maintaining services and utilities and providing transport and logistics. The UK has some of the world's greatest cities; showcasing RAS will give the UK a global advantage in providing capability and expertise.

Inspection and maintenance of infrastructure and historic buildings without scaffolding, integrated personal transport that enables better traffic flow, and a supportive community through assistive living are some of the benefits RAS provides a Smart City

The UK has particular strengths in design, research, finance, and engineering services which could account for up to 25% of the total Smart Cities market. The UK understands cities and how they work, its mixture of the traditional and the modern provides a challenge and an opportunity. The UK innovation matrix is already engaged in developing transport, communications and big data services to enhance city efficiency. Integrating RAS into this mix is the most obvious next step, setting standards, trialing systems and gaining a competitive edge.

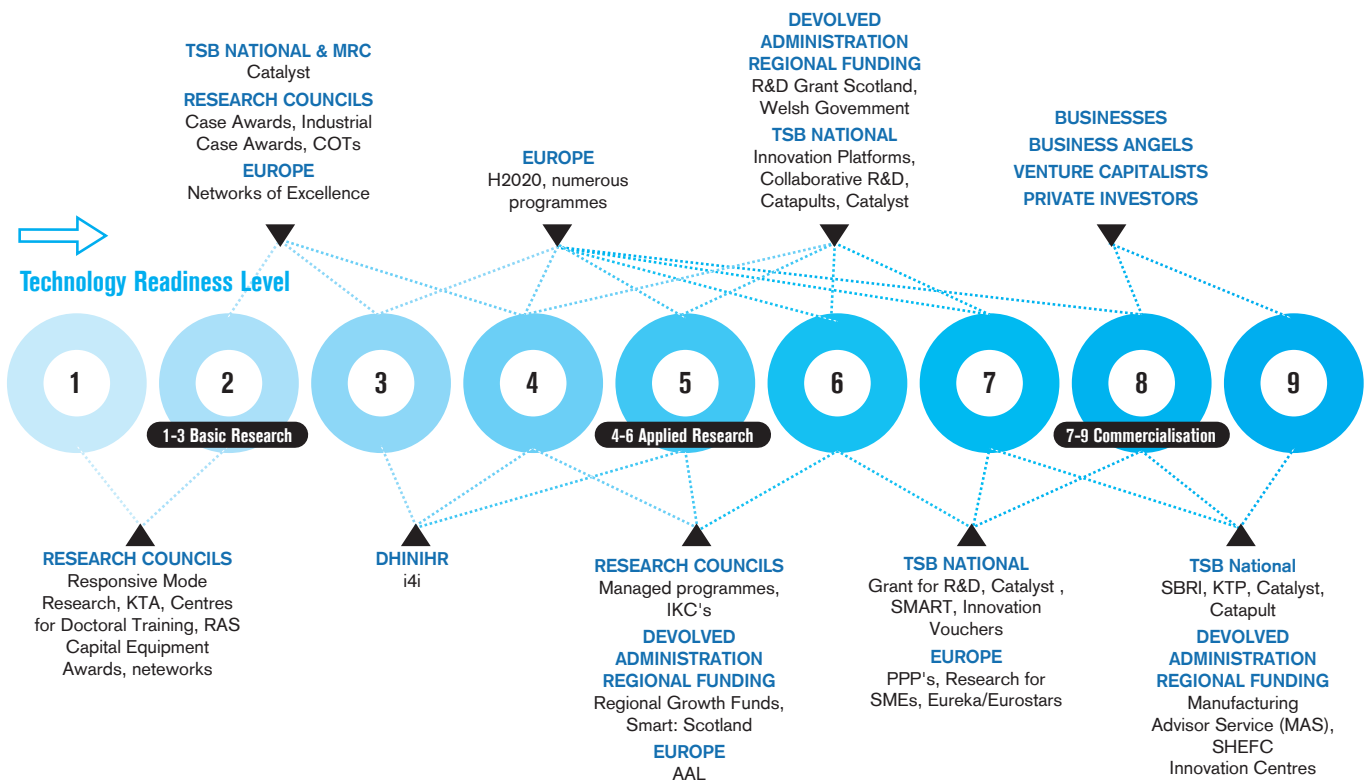
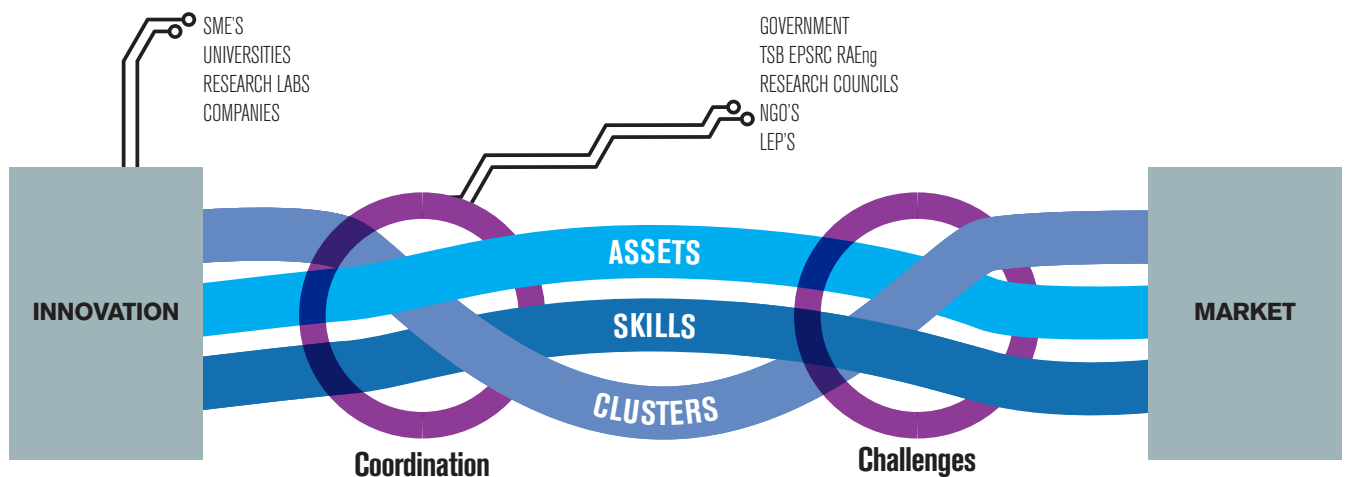


Fig 3: Public Instruments of investment to support implementation of a RAS innovation pipeline

## 4.0 Strategic Actions

### Strategic Themes

Turning invention into innovation on this scale involves more than planning. It involves establishing a vision and a framework within which plans can be formulated and executed. To this end we propose 5 areas of strategic activity to realise the vision of a successful and vibrant RAS innovation ecosystem in the UK (fig 4).



### RAS in Action

## Deep Mining

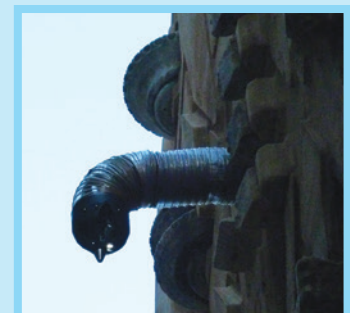
The UK is fortunate to have a wealth of valuable underground mineral resources that are potentially accessible with deep mining technology.

This geology has enabled us to become world leaders in the development of technologies for extraction and refinement as well as decarbonisation, decommissioning and recycling, areas which will help make such industries sustainable and aligned with our international commitments to develop a low carbon economy.

While much of the world's supply of minerals derives from surface mining, high-grade surface deposits of many critical resources are being rapidly depleted. This means we should expect more reliance on deep mining, subsea mining, and recycling. With temperatures in future deep mines likely to exceed 100°C, the costs of supporting humans in these conditions will represent more than 60% of total mining cost.

The use of robot teams will therefore be essential for future deep mines, allowing the UK to maintain leadership in an industry of significant value to the national economy. Government and industry investment in this area will enable us to capitalise on existing mining infrastructure to develop and test novel mining technologies.

Robotics innovations in this field will help to promote collateral advances across a broad range of related domains, including emergency services (particularly search & rescue and fire-fighting), nuclear decommissioning, waste management and space exploration.



## 4.1 RAS Coordination

### Ensuring the strategic use of the UK's RAS resources

The UK has all the required elements to create an effective RAS Innovation Pipeline. Without coordination this opportunity will be lost. Fragmented effort will not generate the focused energy needed to stimulate innovation and deployment in the UK that would then secure export markets. The UK is in a unique position to deliver a joined up successful approach to RAS due to its well-aligned funding agencies and their strong connections with industry and government. Active Government coordination of these instruments of investment is critical for the UK RAS strategy.

#### The main focus of this activity will be to:

- Create active dialogue between the primary agencies (BIS, RCUK, RAEng, TSB, Catapults, Regions) around the strategic RAS innovation agenda and roadmaps in annual planning cycles. Target investment to promote RAS innovation, technology transfer, technology development and address the skills gaps.
- Awaken private finance (VC, Angel, corporate investment) to the RAS opportunity, the potential for novel business models and use cases that build value, with exits in mind.
- Further align and stimulate corporate investment through Joint Industry Projects to support SMEs developing innovative market solutions. Create RAS Entrepreneurs through support and engagement with RAEng Enterprise Hub, RSE Enterprise Fellowships and other schemes such as Centres for Doctoral Training.
- Actively engage regulators, policy makers, end users and the value chain to make the UK *The* place globally where RAS applications and business models can be incubated by providing a transparent regulatory environment for RAS deployment.
- Encourage the use and further establishment of open RAS standards to enable integration, validation, scale benefits and technology re-use.
- Continue engagement with the European Horizon 2020 RAS Strategic Research Agenda and Multi-Annual Roadmap. Build and promote those thematic research areas with potential for UK competitive advantage in both technology and application translation. Create complementarities with UK funding sources.
- Increase intensity and outreach in the wider stakeholder communities through formation of a Leadership Council with senior individuals representing users, value chains and researchers.
- Maintain a relevant and pertinent RAS innovation vision through active strategic agenda and roadmap revision. This will particularly help SMEs to identify market opportunities and potential collaborators.
- Promote the activity to the UK public and the worldwide business community working with the UKTI Innovation Gateway.

## 4.2 RAS Assets

### A UK differentiator to attract global investment

Ensuring that RAS systems are able to make the right decisions, safely, effectively and efficiently in all likely circumstances requires a unique level of testing and functional validation. This is especially important in applications where safety and human interaction are involved.

Large global corporations are already seeking territories where RAS testing can be carried out with supportive regulatory oversight. The UK must rise to this challenge by championing safe operation while at the same time being flexible and innovative in the setting up of RAS test zones.

UK companies will gain insight and competitive advantage through access to high quality testing assets. It is expected that this will also make the UK a primary testing site for global organisations to base RAS work, both because of the range of different test sites but also because of a strong RAS innovation infrastructure.

Within the UK, SMEs will be the drivers of RAS innovation, the employers of choice for talented young engineers and the vehicle for entrepreneurs to create new markets. SMEs are at the heart of the RAS revolution and their access to RAS assets, challenges and resources will be critical to its success.

In many markets RAS technology will face regulatory hurdles. In others, gaining social acceptance may be the key to early adoption. Such barriers are best overcome by engaging with the customer and exposing innovation to the rigours of the real world, but this can only take place in real environments; laboratories are not enough. Deployment test areas are the places in which we live and work; public roads, an actual airport, a working hospital, a farm, a production line, a refinery or nuclear facility.

The UK can kick-start RAS by taking the lead and proactively opening up its regulations to allow RAS devices to operate in defined and controlled spaces. Such a proactive step would attract inward investment, gain valuable insights and attract the best in the world to the UK.

The UK already has these assets, many under public control. They can be made accessible with an appropriate level of support to become valuable assets.

Intangible assets are also vital. Operating RAS in real environments will require revised legal and regulatory frameworks, and engagement with investors and the insurance industry. These are all essential precursors to full-scale deployment.

Enabling the use of these existing assets as RAS Assets is at the heart of the UK RAS strategy.

**RAS Assets will:**

- Unlock markets, creating first mover advantage, and identify valuable intellectual property whilst shaping the emerging landscape.
- Address national challenges thereby creating global opportunities, for example in decommissioning.
- Create a unique resource that will draw companies and investors to the UK.
- Identifying, investing in and branding these assets as RAS Assets is an essential component of building a viable industry.

## Examples of Tangible RAS Assets

- **Legacy nuclear facilities**  
Will host innovative and effective nuclear decommissioning.
- **UK's deep mines**  
Will assist in the development of deep mining technology.
- **Underwater centres**  
Will serve to drive capability in multi-vehicle aircraft black box search and maintenance of underwater infrastructure.
- **Intelligent, mobility-friendly towns**  
Will provide an urban laboratory for vehicles with 24-7 autonomy.
- **Airfields and the surrounding airspace**  
Will enable an improved understanding of the regulatory impact of using unmanned aerial systems and exploration of new commercial models for using our air space.
- **Nuclear reactors**  
Will be an asset for both life extension and new nuclear build.
- **Teaching hospitals**  
Will act as a real-world test bed for innovation and deployment testing for persistent service robots.
- **Factories**  
Will be the test ground for advanced logistics solutions and robotics co-workers.
- **Farm sites**  
Will test the deployment of precision farming techniques using autonomous systems to monitor and manage crops.
- **Above ground energy infrastructure**  
Will be the test bed for evaluating live inspection and maintenance increasing availability and increase safety.
- **Fusion experiments**  
Will serve as an ideal test bed for remote operations that will be essential to ITER and beyond to DEMO, the first fusion power station.

## Examples of Intangible RAS Assets

- **Research strengths in materials science, electronics, communications, digital media and software engineering.**  
Will continue to underpin RAS delivery as an essential component of our future cities, work places, homes, schools and hospitals.
- **Flexible regulation and adaptable insurance and legal framework**  
Will be essential to enable, allow and accommodate new smarter tools in new environments.

## 4.3 RAS Grand Challenges

### Removing barriers to market entry

Grand Challenges and RAS Assets are two of the UK RAS strategy strands that interweave. For each RAS Asset one or a number of Grand Challenges can help open up the asset to potential application providers.

The pre-commercial knowledge gained will provide direct UK market traction for those taking part, seeding the network of suppliers and integrators who are vital to the creation of RAS solutions. Engagement with regulators will be essential to explore how regulatory frameworks can be adapted. These are all critical elements in developing viable RAS value chains.

Grand Challenges need to focus on valuable societal or commercial goals: real-world problems that need solving. Success must be hard won, and the importance of knowledge gained through failure recognised. By involving government departments, issues around public procurement can be explored as a means of addressing national challenges.

Grand Challenges also provide media and public interest stories: they educate and stimulate open awareness of RAS and showcase the industry. A new generation of engineers, technologists and entrepreneurs can be kick-started through exposure to Challenges via the media, schools and universities.

## 4.4 RAS Clusters

### Fostering international competitiveness

RAS will be a source of innovation on a global scale that will attract worldwide competition. To compete in this growing international market-place it is essential that the UK fosters regional RAS Clusters that can act as hotbeds for generating new ideas, new applications and new companies to exploit them. These clusters will have to compete with similar clusters arising in the USA, Europe and the Far East. The UK already has identifiable RAS Cluster hotspots that have attracted funding for doctoral training and capital investment. These need to be stimulated to grow a local ecosystem of innovation where mentoring, finance, business management and training can be readily accessed.

Fostering technology-based clusters is neither a simple nor a short term task. Yet it is essential if the UK is to generate the talent and ideas necessary to grow a globally competitive industry and associated value chain. Such technology clusters are defined by a geographical concentration of high technology firms. However, to be self-sustaining and even to arise in the first place, clusters need high-functioning networking opportunities and facilitation, a strong innovation base with supporting R&D facilities, and a highly skilled and a mobile local workforce. Contributions to success include a world class physical and ICT infrastructure, the presence of large firms who act as customers and anchor the cluster, an entrepreneurial culture, and local access to sources of finance.

UK RAS Clusters will form opportunistically both in terms of market focus and breadth as well as physical location. However, their formation and growth can be proactively fostered. Ideally, RAS Assets will be a key resource for such clusters. Where possible, placing these RAS Assets in regions with an existing strong innovation base (such as recognised leading universities and research centres), with good local infrastructure and with established local customer organisations, will be a key determinant in cluster formation and growth.

#### **Other actions that will facilitate RAS Cluster growth include:**

- Support for networking activity amongst innovative companies in emerging clusters.
- Encouragement of local skills base growth through such measures as targeted doctoral training, apprenticeships and employment tax breaks.
- Raising awareness amongst venture capital and business angel groups of the long term opportunities of RAS together with specific investment incentivisation schemes beyond the Enterprise Investment Scheme (EIS).
- Support to the growth of an entrepreneurial culture amongst RAS students within local HEIs.
- Investigation of other international RAS Clusters for lessons learned.

An initial action will be to maintain an up to date RAS cluster map, building out from the Witty heat maps, looking at major investments and world leading groups, and to further promote regional contacts and events to support organic growth in the ecosystem.

## 4.5 RAS Skills

### Creative people at the heart of our economy

RAS is characterised by the integration of a wide range of different technologies, including materials science, electronics, communications, digital media, AI and software engineering. All of these are UK strengths. The integration of RAS systems and their deployment require technical skills at all levels from researchers to technicians.

It will not be possible to achieve the vision in this strategy without a strong skill base. It is vitally important that investment is made at an early stage so that innovation is not starved of its primary resource.

The provision of skilled researchers in RAS technologies who can move with confidence between academic and industrial organisations are critical to making the UK a world leader in RAS. The Perkins Review of Engineering Skills states that the UK economy will require 100,000 new professionals each year. As the RAS market grows it will be an important consumer of skilled engineers and scientists and may add to this requirement. RAS fellowships and apprenticeships are key needs.

Support and mobility of people is at the heart of successful research. To build a RAS skill base EPSRC has funded four new centres for doctoral training. Skills development will be needed along the career path to retain and nurture expertise in the UK and attract new people from overseas. Critical to this will be support for leading academics to push the RAS agenda forward, to make new collaborations, to source wider research expertise, to overcome technical barriers, and to engage with industry partners who will use these technologies.

This strand must also ensure that the best of UK innovators meet the best of UK entrepreneurs, mediated by RAEng,

The Knowledge Transfer Network-,UKTI and others. This partnership is critical to the successful generation of the new businesses RAS will spawn. Many of the markets for RAS will require inventive and original thinking to challenge current practices and create new market strategies.

To that end, this strand will support and encourage leadership, networking and engagement between complementary areas and with industry. It will further enable training to support company foundation and growth from the research base, and open ended training activities in the research base on novel and timely technological developments.

The nurturing and development of a vibrant and innovative RAS infrastructure is vital to the success of the RAS vision. Skilled people are the foundation for everything this strategy hopes to achieve.

#### RAS in Action

## Surgical Procedures

The use of RAS in surgery has already improved diagnostic accuracy, increased surgical dexterity and improved surgical outcomes.

Coupled with advanced imaging and sensory feedback complex procedures can now be carried out more easily. RAS has already enhanced surgical practice and is set to continue to revolutionise it.

The future will see increased synergy between the surgeon and their tools, providing feedback to inform the 3D extent of the surgical site, adapting to the patient in real time. Lightweight tools will be able to amplify the surgeon's skill, remove tremor and operate with micro-scale forces on delicate tissue well beyond the capabilities of human precision. Surgical tools will begin to learn common procedures from the surgeon, as they operate, able to learn best practice and enhance consistency by guiding the surgeons hand during repetitive tasks.

A new generation of RAS tools will fit into the existing procedures that surgeons execute every day, they will enhance rather than replace, they will improve outcomes and reduce the impact of surgery. Coupled to medical imaging systems, interfaces that respond to where a surgeon looks and real-time diagnosis of the patient, RAS will enhance the range and success of procedures. The resulting improvement in outcomes will reduce costs, decrease time spent in hospital, and reduce the side effects of surgery.



## 5.0 Delivering Progress

### Making a public commitment to RAS

Public engagement and support for the 5 themes in this strategy will be key in launching the UK as internationally leading in both creating and capturing the value from emerging RAS technology as it impacts on the industrial sectors. Coordinating support along the innovation pipeline, as recommended here, provides UK with edge internationally.

#### **Ensuring RAS ideas move along the innovation pipe to market requires the following:**

- Awareness in the market sectors of the opportunity presented by RAS technology.
- The clear demonstration of technical possibility within each sector and application.
- An innovation landscape that enhances opportunity and growth.
- A proactive and fair regulatory framework that promotes good practice and is accessible.
- A strong base of skills and research from which innovation can flourish.

#### **In return RAS provides the opportunity to:**

- Create wealth from innovation and build a stronger more competitive UK economy.
- Sell UK expertise and systems into a global market.
- Address barriers to market adoption and create a positive environment in the UK for inward investment.
- Address societal challenges.
- Demonstrate ethical and responsible innovation.
- Stimulate interest in STEM subjects at all levels.

It is clear that the impact on the UK economy over time from RAS will be significant. It is also well understood that early mover market advantage has a long and lasting impact. Only national level initiatives and actions can achieve these high level goals. Failing to invest will result in piecemeal development in sector silos, patchy postcode-based activity, reactive regulation, and a “wait and see” attitude. UK will be overtaken by other nations, and will miss the key opportunities for market penetration and dominance.

#### **Government investment can stimulate a step change.**

- Investment in innovation will leverage private investment so that the best innovation reaches the market and creates wealth and jobs.
- Government can be a first customer of RAS in public services thus priming the market and addressing societal needs.
- Government has a responsibility to enable the public to have access to the best tools.
- Government can shape regulation to ensure RAS technology is tested and used in UK markets first in a controlled and considered manner.

#### **Public investment will be used to:**

- Drive and support the strands in this strategy that are focused on achieving the vision.
- Leverage private investment in infrastructure and RAS tool development.
- Create public awareness and engagement in the issues surrounding RAS deployment.
- Reduce investment risk by enabling open demonstrations of RAS capability and promoting opportunity.
- Build the skill base and fund research fundamental to RAS.
- Ensure societal challenges are addressed where the public benefit outweighs the private cost.

## 6.0 Outcomes to Mark Success

RAS innovation success will lead to, products, services and subsequent effects in different market sectors. In isolation, however, these are only part of the story. Since RAS is pervasive, success will manifest itself in more general ways, for example:

### An established innovation pipeline

Success is a healthy UK market for RAS products based on an innovation pipeline where certification processes are well established for each sector. Success will be marked by an array of SME suppliers with a wide range of effective technology able to meet the requirements of multiple markets.

### SMEs as inventors and innovators

Success will be marked by access to finance and assets needed to develop and trial new products. Larger organisations are aware of the RAS opportunity and open to the needs of collaboration and open development. Clear regulatory paths will be established in each sector and there is access to RAS specific expertise, both in academia and the service sector.

### Multinationals as end users

A sign of impact will be multinationals investing in the UK RAS sector. A significant draw will be a regulatory infrastructure aligned with assets. In time a strong RAS supply chain with an excellent science and technology base and well trained workforce will make the UK a great place to do RAS business.

### Equity investors as participants

Success will see an increase in investment for RAS based businesses as a result of attractive returns. Specialist VC and Angel funding opportunities tuned to the needs of the RAS sector will emerge. Investors will see a stream of skilled researchers eager to test their innovation in the market, with a government able to apply early stage support for investment through tax incentives.

### Leading RAS researchers clustering in UK ecosystems

Researchers will be drawn to thought leaders and places where there are opportunities for world-class research and opportunities to create start-ups. A mark of a vibrant research community will use state-of-the-art UK supplied equipment to pioneer new science and technology.

### UK economy growing with social gain from delivery of services

At a national level success will be measured by the contribution to the economy in both financial and social terms. RAS technology will help UK business to be more competitive, find new markets, and deliver better services. The UK will grow by allowing novel innovation to find its place in the market.

Success will be seen as a measurable and attributable social gain in service delivery, improved quality of life and other social indices from RAS. Success will also be seen in improved efficiency in government services, in healthcare, infrastructure and in reduced liability in the decommissioning of long term assets.

### General public acceptance and comfort using RAS technology

Smarter RAS tools will be for people to use in their workplaces and in their homes. In particular these tools will enable a better quality of independent living for an aging population.

It is inevitable that as we create these tools they will change us and they will change our society. It is our shared responsibility to ensure that the direction of UK research and innovation is shaped in the public forum to generate wealth and address the challenges that future generations will face.

## 7.0 Conclusions and Recommendations

This strategy seeks to establish the UK in a leading position in the international race to be providers of new and as yet unforeseen RAS products and services with the potential to be disruptive in value chains.

This will be achieved by using a range of RAS technologies applied to value creation opportunities in a range of industrial sectors. Our competitive advantage will come from the availability of tangible RAS assets which are physical real world locations where RAS systems can be exercised. These will be supported by intangible RAS assets including a sympathetic and safe world-leading regulatory environment and Grand Challenge competitions. These will focus development efforts around useful capabilities, capturing the imagination of the public and engaging those businesses that will benefit from such capabilities being commercially available.

By coordinating assets and challenges with the other recommended activities such as establishing RAS clusters and ecosystems, and combining with strong leadership and skills training development in innovation and the research base, this strategy will provide the UK with the core tools to win in the commercial race, capturing value, creating jobs growth and wealth.

**To achieve these, we recommend the following next steps:**

1. Invest further in the five RAS strategy strands: assets, challenges, coordination, clusters and skills to build the UK's RAS balance sheet.
2. Establish the means for funding agencies to formally work together in execution, so that ideas, people and activity flow readily from basic investigation through early stage demonstration to fully trialled commercial product.
3. Establish a RAS Leadership Council to engage with senior leaders across a range of sectors in industry, academia and Government, providing independent advisory oversight of planning and execution of the strategy.
4. Further develop engagement with EU, Investors and UK/overseas corporate resources to fuel the development of the 5 strands.
5. Consult more widely on potential Asset and cross sector Grand Challenges.
6. Further develop dialogue with those involved in standards and regulation, for example BSi, CAA, to develop more detailed thinking.
7. Extend outreach and public engagement activities to continue changing public perceptions.
8. Articulate internationally (e.g. through UKTI) to make businesses and investors aware that UK aims to be the best place to invest in taking RAS technologies to market.

### RAS in Action

## Manufacturing

In 2012 the manufacturing sector contributed £139 billion to the UK GDP, a significant figure expected to increase over time.

Manufacturing businesses play an important role in the UK economy, investing more in R&D than those in any other sector, encouraging innovation, and accounting for more than half of all UK exports. It is widely recognised that the UK has much to gain by maximizing the RAS uptake in this sector.

RAS will improve competitiveness, enable new manufacturing processes, and is strongly expected to increase employment throughout the supply chain. The opportunity to reshore SME and mid scale manufacturing offers greater flexibility, wider product diversity and a faster response to changing market need. RAS will enable a seamless digital production environment and easily reconfigurable factories and collaborative human robot systems thereby increasing efficiency and competitiveness. There is a real opportunity for the UK to become a manufacturing centre of excellence and to profit from our innovative design and product development skills on a global scale.



## 8.0 Contributing Team

### Members of the RAS SIG Steering Group:

David Lane (Chair), Rob Buckingham (Co-chair), Tony Balmer, Joe Barnard, David Bisset, Phil Brown, Lambert Dopping-Hepenstal, Sue Home, Robert Leese, Neil Mantle, Chris Melhuish, Kedar Pandya, Geoff Pegman, Stephen Sanders, Susan Soulsby, Richard Walker, Steve Welch, Phil Williams and Guang-Zhong Yang.

In addition, individuals from the many companies, research groups and public servants from across the UK, including large and small organisations, SME and corporate, governments and funding agencies, who participated in deep dive workshops and other networking events during 2013/4, providing ideas and perspective, and helping to prune and distil this strategy.

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## Health and Social Care

The world's population is ageing as well as growing. 10.8 million people in the UK are aged 65 or older, and this number is expected to reach 19 million by 2050.

The high staff turnover and low wages in the health and social care sector have led to growing concern about poor standards of care that impact the dignity of the most vulnerable.

This situation will have severe economic as well as social repercussions – a 2010 study forecast that annual UK public expenditure on long-term care will increase from £11.3 to £31.1 billion by 2032, with private expenditure due to rise from £7.3 to £22.4 billion in the same period. There is consequently a pressing need to develop new RAS technologies that allow people to live longer in their own homes.

The UK is well placed to pioneer advances in this field, thanks to its local networks of interlinked facilities including university research centres, hospitals, rehabilitation clinics and long-term care settings.

A large-scale initiative is now needed to establish a suitable national research infrastructure in this field. It is important to note that the introduction of robots in healthcare should occur with sensitivity towards public concerns about the possible dehumanisation of care.



**The Robotics & Autonomous Systems Special Interest Group is an open access community network for everybody who is interested in the subject.**  
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