M Squared is an award-winning, high-growth photonics and quantum technology company that has taken a leading industrial role and been a highly active participant in the National Quantum Technologies Programme. We develop advanced, high-value lasers, electronics and integrated systems for quantum technologies, life sciences and sensing.

**State of the UK’s quantum industry**

The current state of the UK quantum technology industry shows a number of highly active innovative companies, committed to investment and building upon native capabilities in key areas of strength and strategic focus. The number of participants has been limited during the initial phases of the programme, although the interest and overall investment continues to grow each year.

The UK quantum industry received considerable investment in 2015 as the government made £270 million worth of funding available to help realise the full potential of the academic and commercial innovation which exists in the UK. As part of the initial investment, the EPSRC recognised the benefits of supporting specific areas of collaborative excellence and helped to fund the creation of a network of hubs, led by the universities of Birmingham, Glasgow, Oxford and York.

To date, the support given to regional clusters surrounding research institutions has proven an excellent tool for harbouring the results of cooperation between academia and industry. It is without doubt that the UK has the knowledge-base and ambition to become a leading player in the global quantum community and since the formation of the UK National Quantum Technologies Programme considerable progress has been made in many key areas, that will be discussed below.

Significant developments have also been made on the recommendations of the Government Office for Science’s 2016 report: 'The Quantum Age: technological opportunities'. Our own work, undertaken in collaboration with research institutes, commercial partners and the network of Quantum Technology Hubs has led to significant advances in the areas of cold atom sensing, quantum information processing, high-accuracy timing and advanced imaging. The broader community has taken on board the steps outlined in the report, with evidence of the specific technical recommendations being implemented along with the more general steps on the necessary structural reforms.

It is now vital that key policy-makers recognise that quantum is not a passing trend. This is a technology that can bring benefits that will change the world and the UK must be active in trying to realise the enormous benefits of this technology.

To date industrial participation appears to have come from a group of committed SMEs with limited overall resource, or a couple of large companies making a modest strategic investment in these emerging technologies.

As the National Programme has grown and successful coverage of events such as the National Quantum Technologies Showcase each November has raised the profile, there has been a
noticeable increase in the participation of major multinational corporations. The participation of such companies has been primarily exploratory and it is clear that more ground will need to be covered in technology development and demonstration terms before significant investment will be forthcoming from UK blue chip companies.

**Successes to date**

M Squared is uniquely positioned to realise short, medium and long-term benefits from the National Programme due to its commercial proximity to the global quantum research sector. The first commercial outcomes from our portfolio of Innovate UK programmes are now being offered to existing customers, supported by the growth of our in-house capabilities that have been leveraged to deliver additional value to our customers, fuelling ongoing scale-up.

The alignment of the programme and our strategic goals gives us an opportunity to continue to deliver game-changing technology across the sector and going forwards we will ideally remain closely aligned with the future of the National Programme.

One example of the benefits gained from working with the programme were seen in 2017 when M Squared produced the UK’s first commercial Gravimeter. This is a realisation of a quantum technology that could pave the way for transformative new applications in many other sectors – such as the detection of new oil and gas deposits, surveying unknown underground infrastructures such as pipes and cables, and geological surveying.

The Gravimeter was an Innovate UK-sponsored project and part of the UK Quantum Technology Programme. The expertise of M Squared in laser engineering and system integration was combined with the academic excellence of Kai Bongs’ group at the University of Birmingham to create a collaborative team of experts that developed a device capable of delivering highly sensitive gravity measurements.

During this time M Squared was also working with Professor Ed Hinds’ group at Imperial College London, developing complementary quantum technologies as part of the UK Quantum Technology Programme. Another Innovate UK-backed project that focussed on developing the UK’s first commercial quantum ‘3D inertial sensing’ device. This technology measures acceleration using atom interferometry – supporting high-precision satellite-free navigation for use in mining, shipping and other transport means where GPS is hindered by dead areas and the effects of terrain and weather.

**Recommendations**

For the industrial sector the long-term commercial potential of quantum is well evidenced and in most cases remains a future prospect rather than one that will be realised imminently. The reality is that whilst significant commercial opportunities can be realised over both near-term and longer-term timescales, the sector as a whole is characterised by significant technical and market risks. On the delivery side, there are highly complex systems requiring advanced engineering developments, whilst the target markets are invariably loosely-defined or are so disruptive that the route to market remains to be mapped out.
It is important to emphasise the role of adequate funding support in the success of the programme. M Squared is well positioned to undertake extensive reinvestment of our own revenues and capital due to our proximity to short-term market opportunities. Very few, if any, other companies in the UK have the will or the capability to invest their own funds to the same extent.

The investment in the initial phase was weighted heavily towards the academic research base, who have executed their strategic research plans with an active industrial advisory participation in the overall governance. The mechanisms for industrial participation and knowledge transfer with the Quantum Hub networks has been limited by restrictive academic funding rules.

The typical scenario would see a university awarded funds on the provision of matched funds from an industrial participant. In order to reach worthwhile funding amounts to realise basic knowledge transfer requires the commitment of industrial collaborators to invest disproportionate amounts of their own funds before they can even begin to evaluate and develop the technology. At the typical technology readiness levels of the Quantum Hub outputs, this is severely limiting for realising true commercial impact. It is important that the National Programme evolves to factor in the growing maturity of Hub outputs and acknowledges the needs of companies that are positioned to bring technologies to market.

In order to build on the industry successes seen as part of the Quantum Hubs Network and accompanying collaborative partnerships, there is a need for renewed national funding that will help to greatly accelerate the industrial delivery and deployment of private sector resources into the quantum-technology sector.

Any slow-down in the commitment to the National Programme will expose the UK sector to the risk of falling behind other nations. The role of Innovate UK will be important in the future Industrial Strategy Challenge Fund activities and any subsequent National Programme funding.

The topical calls during the first phase of the National Programme have provided periodic funding opportunities that have been utilised by a healthy variety of institutions. M Squared has benefitted greatly from the funding made available by Innovate UK., which has enabled several studies with a number of academic and industrial collaborators.

However, to help support further benefits from collaborative projects we would recommend that Innovate UK look to increase funding for the large-scale quantum system integration activities that will ultimately deliver the high impact outcomes that have been targeted at the National Programme level.

Beyond levels of funding, there are structural reforms which if implemented would increase the extent to which Innovate UK investments effectively support the UK’s ambitious quantum businesses and further align requirements. We would suggest that Innovate UK look to review the extent to which any one company can participate in the programme as to avoid limiting the overall investment that is made in a given funding round.

In order to maximise the efficiency of the Innovate UK funding rounds there are issues of organisational process and structure which should be looked at. In the latest funding round, several
unresolved bureaucratic issues at Innovate UK led to delayed project starts, significant uncertainty in private sector investments, and in some cases a slow-down in the job creation that could have resulted. It is clear that in order to reach the targets that the community has set out, the funding landscape needs to reflect the magnitude of the challenges being faced.

Companies with a proven track record should be given the opportunity to push boundaries and allowed the best possible conditions to meet the innovation needs of the National Programme.

Furthermore, the support required from key players in the UK’s quantum technology landscape to make the overall programme a commercial success is considerable in terms of funding and strategic commitment. The role of government is vital due to the infancy of recent advancements in quantum technology, which leaves the industry particularly exposed to overall risk and the uncertainties in the emerging commercial landscape that can hamper investment. These issues are compounded when the presence of formidable international competition in the most compelling sectors is considered.

The academic base, both within and beyond the established Quantum Hub network, will play a key role in fundamental developments and knowledge transfer but perhaps more crucially in establishing a quantum-capable workforce. It is vital that efforts are made to help ensure the UK has a stable and highly skilled talent pipeline with proven technological skillsets, along with the motivation to take ideas through to commercial realities.

The role of the Defence Science and Technology Laboratory (Dstl) and other state institutions with short-term strategic application needs, will be of critical importance for industrial entities seeking to make significant leaps in functionality through the delivery of highly complex integrated systems, which would go beyond the reach of typical Innovate UK-type projects.

It would be of great advantage to the UK government, academics and industry leaders if a system of benchmarking was to be initiated. Knowing how much other countries are spending on areas that will be touched by advancements in quantum, such as the investment in solving societal problems, defence and security, could help align UK priorities and efficiencies.

There is a growing need to increase the speed from which technological advancements leave the research laboratory and enter into the industrial base. While it is assumed that once developed the technology within the universities is easily rolled out into industry, this is simply not the case. In the current environment and under certain structural conditions it is very costly and time intensive to transform the technology into an industry. Countries such as Canada are further ahead in terms of becoming industrialised in quantum and are seeing the benefits of shortening this process. There is specific support from local government which invests in new research buildings and is creating dedicated quantum funds.

There is also a significant risk that certain areas of focus are deprioritised due to perceptions that the UK cannot compete or catch up, such as in quantum computing where the level of investment in the US dwarfs any other national programme. It is clear that even if key breakthroughs are made elsewhere, the opportunities for a native UK capability in each strategic area can lead to invaluable dividends in the application ecosystems and supply chains that can play to the strengths of the UK industrial sector.
The challenges associated with knowledge transfer for highly complex technologies should not be underestimated. M Squared has a long track record of ambitious intellectual property licensing and technology transfer projects, and the difficulties associated with this process are formidable. The ability for academic groups to commit adequate resources to these activities suggests that sufficient funding is hard to gain, and prioritisation of conventional publication outputs, for example, has had the effect of skewing motivations. Exceptions to this can be seen within the UK National Programme and the Quantum Hub for Metrology and Sensing, for example, have shown a notable commitment to this process albeit within the limited funding regime.

Further challenges can be seen by UK businesses in scaling up. Historically, Britain has a strong track-record in starting up companies, but these start-ups often see challenges in growing from around the 100 employee-mark to reaching over 1,000. Alongside a government commitment to the quantum industry, there must be adequate support and funding for businesses within the industry to scale-up effectively, in order to realise the UK quantum industry’s high-growth potential.

The role of intellectual property management will play an increasingly important role in future phases of the National Programme. The universities active in the field have begun thinking seriously about protecting their own foreground intellectual property. The access to this IP has generally been open, however, the expectations relating to the value of patents and know-how needs to be rooted in the commercial realities of the sector. It should be recognised that companies should have fair access to IP generated by the National Programme, with consideration given to the overall risks and the timelines for validating and developing profitable products based upon any licenses.

What could the UK achieve?

The UK quantum community is seen globally as a well-coordinated hub, which at this stage has shown a strong willingness to make investments early and commit to the coming quantum revolution. Britain has gained an international reputation for being home to some of the leading scientists in the field. It is therefore vital that we build on the pool of leading scientists and early funding to ensure that we are thinking of quantum not as a future industry but set aside cash now and guarantee the sector can prosper going forwards. We should help to spread the message that society has passed from the era of analogue, then digital and now quantum is on the horizon.

There are several roles that the government can adopt in order to further support the UK’s community of quantum technology businesses, as a customer, a convener, and a catalyst to industry, helping to speed things up and sponsoring progress.

Taking M Squared as an example, the government could task us to help solve societal problems using the technologies that we develop and intervening with funding and tax relief when appropriate.

M Squared has developed a quantum computing programme proposal but we have not managed to gain any traction from the government at this stage. There is an underlying sentiment that suggests that the UK shouldn't fully engage because the US tech giants, for example, can fill the
knowledge and funding gaps. However, there is space for lots of people to do it and address different challenges or find different ways of solving the same challenges.

The UK quantum community is very competitive globally, particularly from an academic viewpoint is a world-leader in producing quantum research. It is however important that the UK sustains this position and keeps pace with the technology powerhouses of China and the USA who are currently making large investments into both quantum research and commercial applications.

The UK Quantum Programme has shown strong leadership in the field but now it is time to invest more strongly and more boldly to help deliver the new industries that will have implications across society. A strategic commitment is not just about helping traditional industries evolve by adopting new quantum technologies but supporting brand new companies and industries to emerge.

The UK benefits from being a small geographic region and when compared with say the US and Canada, physical distance and a lack of connectedness can lead to disparate initiatives that could benefit from increased collaboration. Britain’s quantum hubs distinctively benefit from being closely linked, it is much easier to collaborate right across the country. Quantum hubs where academia and industry work in greater alignment are the key to realising commercially viable products more efficiently and at a faster rate, we would encourage the government show greater support for these relationships.

Concluding remarks

To date, no other UK company has collaborated as widely or demonstrated as many commercial breakthroughs in quantum components, subsystems, integrated devices or applications. As a highly collaborative and genuinely global company we are convinced that international collaboration should play a key role in our National Quantum Technology Strategy. The future of the sector is inevitably rooted in the global research networks that have underpinned much of the work to date.

The highly international nature of these networks means that a national programme that fails to integrate and collaborate with the globally leading research and commercial players will miss out on the cutting-edge outcomes and opportunities.

An obvious topic is the role of the European Union’s Quantum Technology Flagship and the role of the UK in the context of Brexit uncertainty. The UK’s participation in the ramp-up phase, governance and initial Quantum Flagship calls has been significant but perhaps proportionately less than might be expected from the investment already committed by the UK Government.

The UK has developed very strong internal networks as a result of the National Programme and the opportunity to achieve something similar across Europe is a highly attractive proposition, given the collective strength of the EU research pool.

Quantum is a challenging field and success involves all areas of science and computing science, it requires extensive multi-disciplinary cooperation. We are not starting from scratch but standing on the shoulders of giants and gaining ground. In order to make the necessary steps forwards we must appreciate the level and extent of skilled scientists that are required. A massive investment is
Written evidence submitted by M Squared (QUT0024)

needed in skills and education looking to produce the next generation of quantum engineers, scientists and programmers.

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