Appendix 2a: Roundtable Participants

Title	Name	Position	Affiliation
	William Alexander	Technical Director	Thales
	Simon Andrews	Executive Director	Fraunhofer UK Research Limited
Prof	Steve Beaumont	Emeritus VP, Director of QuantIC and CENSIS	University of Glasgow
Prof	Kai Bongs	UK Quantum Technology Hub Sensors and Timing	University of Birmingham
Prof	Gerald Buller	Professor of Physics	Heriot-Watt University
Dr	Caroline Cantley	SSAC Member, and Executive Director	Scottish Research Partnership in Engineering
	Brendan Casey	CEO	Kelvin Nanotechnologies
	Michael Cuthbert	Director	STFC
Prof	Andrew Daley	Professor of Physics	University of Strathclyde
	Anke Davis	Senior Portfolio Manager	EPSRC
	Martin Dawson	Professor, Director of Research in the University of Fraunhofer Centre for Applied Photonics and Strathclyde's Institute of Photonics	University of Strathclyde
Dr	Sara Diegoli	Director	QuantIC / University of Glasgow
	Chris Dorman	VP and General Manager	Coherent, Scotland
	Katharine Dunn	Head, Quantum Technologies	EPSRC
Dr	Stuart Fancey	Director of Research and Innovation	Scottish Funding Council
	Roger Fenske	CEO	Edinburgh Instruments
Prof	Allister Ferguson	Professor of Photonics	University of Strathclyde
	Carolyn Fishman	Policy Manager, UK Industrial Strategy and Technologies Team	Scottish Government
Prof	Maggie Gill	Chair, Scottish Science Advisory Council and Professor Emeritus …	University of Aberdeen
	Steve Greenland	Managing Director	Craft Prospect
Prof	Duncan Hand	Professor	Heriot-Watt University
	Sam Johnson	Quantum Lead	Innovate UK
Prof	Julian Jones	SSAC Member and Senior Deputy Principal …	Heriot-Watt University

Title	Name	Position	Affiliation
Prof	Elham Kashefi	Professor of Quantum Computing	University of Edinburgh, School of Informatics
	Graham Kerr	Technical Director	CENSIS
Sir	Peter Knight	Chair of the UK National Quantum Technology Programme Science Advisory Board	
Prof	Stefan Kuhr	Head of the Optics Division and the Experimental Quantum Optics and Photonics Group	University of Strathclyde
Prof	Robert Lamb	Chief Technologist	Optoelectronics Leonardo
Dr	Christopher Leburn	Director & Co-Founder	Chromacity Ltd
Dr	Rhys Lewis	Head of the NPL Quantum Metrology Institute	NPL
	Alasdair Maclean	Policy Officer, Science Advice and Engagement Team	Scottish Government
Dr	Graeme Malcolm	Founder & CEO	M Squared Lasers
	David Mallon	Head of Climate Change Policy and Implementation Unit	Scottish Government
	Stephen Mann	Policy Officer, UK Industrial Strategy and Technologies	Scottish Government
Dr	Una Marvet	Head of Design Centre	Alter Technology
Dr	Roger McKinlay	Challenge Director	UKRI
	Ewan McLellan	Non Executive Director at UniKLasers	Unik Lasers
Dr	Alison McLeod	Senior Programme Manager (Photonics)	Technology Scotland
Prof	Alan Miller	Chief Executive Officer	Scottish Universities Physics Alliance
	Caroline Murray	Policy Officer, Science Advice and Engagement Team	Scottish Government
	Claire Ordonyo	Business Development Manager	Scottish Research Partnership in Engineering
Prof	Miles Padgett	Kelvin Chair of Natural Philosophy and PI for QuantIC	University of Glasgow
Prof	Douglas Paul	Professor of Semi-Conductor Devices	University of Glasgow
Prof	Derryck Reid	Professor	Heriot-Watt University
Dr	Najwa Sidqi	Knowledge Transfer Manager: Emerging Technologies	KTN
	Edward Thomson	Head of Low Emission Vehicle Policy	Transport Scotland SG

Title	Name	Position	Affiliation
	Joanne Ward	Science Advice and Engagement Team Leader	Scottish Government
Prof	Jeremy Ward	Professor of Industrial Practice	University of Strathclyde
Prof	Martin Weides	Professor of Quantum Technologies	University of Glasgow
	Wenmiao Yu	Director of Business Development	Quantum Dice

Appendix 2b: Invite letter and Programme

Roundtable: Opportunities for Quantum Technologies to contribute to the Scottish Government's Vision for Scotland
January 18th, 14:00–16:30

Introduction And Aims

The Scottish Science Advisory Council (SSAC) provides independent advice and recommendations on science strategy, policy and priorities to the Scottish Government (SG).

The UK Government's National Quantum Technologies Programme Strategic Intent 2020 document highlights that quantum technologies have the potential to transform our economy and address societal challenges due to capabilities they could offer to a range of sectors. Quantum sciences, including photonics, are key strengths of research and industry in Scotland.

SSAC has been asked by the SG UK Industrial Strategy and Technologies Team to provide advice and recommendations on how Scotland could best capitalise on its quantum capabilities, including potential contributions to achieving Net Zero by 2045, healthcare, life sciences, finance, aerospace and other key economic and societal challenges.

Key stakeholders from universities, industry and the public sector have been invited to participate in this roundtable to help identify the key issues and sector priorities for commercial benefit, to recommend the interventions and support mechanisms to support delivery of Scotland's strategic goals.

The outputs from the roundtable will inform the SSAC's report to the SG on the worldwide status of quantum technologies, Scotland's current positioning and competitiveness, and will be used to highlight opportunities and challenges.

Programme

14:00 - 14:05	Welcome and Objectives	Prof Julian Jones (SSAC)
14:05 - 14:15	Overview of SSAC	Prof Maggie Gill (SSAC Chair)

14:15 - 14:25	Policy Overview	Carolyn Fishman (SG)
14:25 - 14:35	Technology and Market Overview	Dr Najwa Sidqi (KTN)
14:35 - 14:50	General Discussion	CHAIR: Prof Julian Jones (SSAC)
14:50 - 15:20	Breakout Groups (30 min)	
	(1) Quantum Computing	CHAIR: Dr Najwa Sidqi (KTN)
	(2) Quantum Communication	CHAIR: Dr Stuart Fancey (SFC)
	(3) Quantum Sensing & Imaging	CHAIR: Prof Maggie Gill (SSAC Chair)
	(4) Quantum Sensing & Imaging	CHAIR: Prof Alan Miller (SUPA)
15:20 - 15:40	BREAK (20 min)	
15:40 - 16:20	Breakout Summaries by Group Chairs	CHAIR: Dr Caroline Cantley (SSAC)
16:20 - 16:30	Wrap-up and Next Steps	Prof Julian Jones (SSAC)

Framework For Breakout Discussions

There are four pre-allocated breakout groups:

Quantum Computing	Breakout Group '1'
Quantum Communication	Breakout Group '2'
Quantum Sensing and Imaging	Breakout Groups '3' & '4'

Each breakout group should explore and discuss:

1. **Strategic priorities where quantum technologies will play a critical role towards delivery of Scotland's future vision**, including roadmaps to Net Zero 2045
2. **Opportunities for quantum technology development and applications**, aligned with Scotland's research and industry strengths (including relative maturity and competitiveness) and sector opportunities for commercial benefit including their contribution to offshore supply chains
3. **Challenges and barriers to achieving Scotland's strategic goals**
4. **Interventions and support mechanisms required to support delivery of Scotland's strategic goals**

The following aspects of the overall ecosystem could be considered during discussions:

a. Technology, research, innovation
b. Skills and workforce
c. Business models

d. Collaboration and networks (cross-sectoral: industry / public sector / academia)
e. Supply chain resilience and competitiveness
f. Circularity and sustainability
g. Adaptation and transformation
h. Policy and funding
i. Societal issues

Appendix 2c: Quantum Technologies – Summary of Breakout Group Comments

Key To Breakout Groups

[QComp1] Breakout Group 1 – Quantum Computing

[QComm2] Breakout Group 2 – Quantum Communication

[QS&I3] Breakout Group 3 – Quantum Sensing and Imaging

[QS&I4] Breakout Group 4 – Quantum Sensing and Imaging

STRATEGIC PRIORITIES where quantum technologies will play a critical role towards delivery of Scotland's future vision, including roadmaps to Net Zero 2045

Summary Session Comments

Quantum technologies are an enabler for key strategic goals e.g. Net Zero.

Quantum technologies enable a more resilient society.

Sectors – pharma; finance; space; manufacturing; health.

Breakout Group Comments

[QComp1] – There is already a quantum hub centred in Scotland. There will be an evolution of the national programme to stage 3, and there is a robust plan for the hub. One should be cautious about overselling quantum computing for Net Zero when there are other technologies which can help solve the problem now. Quantum computing will be important, but on a scale not yet certain. One should also be aware of the current limitations of quantum computing and how much it can contribute to solving challenges.

[QComm2] – Fintech and space sectors are key to economic development and the user communities need to be joined up in their understanding of the potential of quantum technologies.

[QComm2] – Data infrastructure is critical for the future. Quantum technology will secure communications against threats which will in turn secure national infrastructure. Without secure data infrastructure there is no economic development.

[QComm2] – Fintech and space are two obvious areas of importance and there is a real need to make sure they are joined up. Scottish Government could potentially have a strong influence on opportunities for quantum technology development for space applications.

[QComm2] – Achieving an understanding of quantum technologies is especially important for institutions who deal with sensitive data e.g. NHS, or the British Geological Survey.

[QComm2] – The first application of quantum technologies should be in securing communication networks, which are crucial in terms of protecting national infrastructure. This is an absolute key to economic development as without safe and reliable communications networks, companies will not invest and therefore no economic development will occur.

[QComm2] – Scotland is very data-centric. We can make that an economic opportunity, but only if networks are secure.

[QS&I3] – Some of Scotland's strengths lie in producing components, which can have potential to enhance many processes – there are opportunities in the energy sector (e.g. optimisation of onshore/ offshore wind, gas monitoring), health (e.g. imaging for disease diagnosis), and transport (e.g. autonomous vehicles).

[QS&I3] - Analysis of market trends is one way in which companies identify which sectors and applications may provide economic opportunities e.g. replacement of an existing technology with quantum technologies could bring benefits, economic or social, to the sector.

[QS&I3] - The net zero challenge is very broad. Sensing and imaging can contribute to monitoring hydrogen, polluting gases, power cables, and optimisation of onshore and offshore wind. The net zero transition requires intersectoral collaboration as well – across all areas of economy – transport and communications etc; the challenge is to identify specific quantum technology opportunities.

[QS&I3] - Net zero may not be front and centre in quantum technologies development but Scottish Government has made it a top priority so it may become a direct issue for the science base. Identifying possible ways quantum can assist net zero would be helpful. The climate change plan has eight sectors - we should enumerate the possible contributions of the sector science base as set-out in the Climate Change plan.

[QS&I3] - Quantum 1.0 (mobile phones, solar panels, imaging for diseases) has already delivered to customers and has developed products that sell, and Quantum 2.0 naturally follows. We have a healthy academic breadth who are achieving funding in line with Government policy. Government is funding green energy developments but it is essential that they also support the quantum sector to enable companies in the future to run their businesses profitably.

[QS&I3] - What are the applications that have immediate strategic benefits for the economy and society in Scotland? The Innovation Centres were set up to look at what was benefitting the economy (oil and gas, aquaculture, biotech etc). We could do a similar exercise here. What would give the economic players a competitive advantage in quantum? Are potential winners being backed in the strategic priorities for Scotland? There are opportunities for developing supply chains through raw materials, systems, products, end users. Scotland and quantum has considerable strength at the component level.

[QS&I4] – The Scottish research community is good at photonics and has a well-developed community of companies with university links, and so is good at developing commercial products.

[QS&I4] – There is a fantastic ecosystem of companies across the university system. Scotland has dynamic SMEs through to established big players and leading universities.

[QS&I4] - One of the most significant technologies influencing quantum computing is photonics; it would be erroneous to consider photonics is just sensors and cameras, it's the backbone of quantum computing.

[QS&I4]- There are opportunities for quantum and space technology and in sensing and imaging systems.

[QS&I4]- There are applications for quantum sensors for in line battery testing (e.g. project ongoing in Thurso)

[QS&I4]- Future medical applications and devices are likely to emerge.

OPPORTUNITIES for quantum technology development and applications, aligned with Scotland's research and industry strengths (including relative maturity and competitiveness) and sector opportunities for commercial benefit including their contribution to offshore supply chains	
Technology, research and innovation	**Summary Session Comments** Scotland is seen as a European centre of excellence. Quantum technology provides support for the transition to Net Zero and has impact in a wide range of sectors. Drive for Net Zero applications include end of life battery testing; there are opportunities in medical sensing and imaging; in space technology for sensing and communications. Quantum communication offers opportunities in the space sector. Nanofabrication supported by quantum technologies may provide an ability to make new and profitable products. Photonics, imaging and components can cut across many applications. Scotland has diverse strengths. A strong manufacturing presence is important. There are considerable opportunities in in cyber security, large ICT, pharmaceuticals, finance. **Breakout Group Comments** *[QComp1]* – There is rapid growth in hardware and software relevant to quantum technologies across Scottish universities. *[QComp1]* – There are many potential applications across multiple sectors. *[QComp1]* – Net Zero is supported by quantum technologies. Quantum technologies are likely to be good at optimisation problems e.g. better battery materials. There are questions around timescales. There are opportunities for growth in Scotland as quantum developers. *[QComp1]* – Place is an issue: where and why is there a pull around R&D in the Central Belt, and where is the impact of quantum computing going to be felt in the industries applying it in the future? There are arguments for early applications in pharma, finance and manufacturing. There are likely to be high profile users here and we need to be ready with skills etc to deploy quantum computing. *[QComp1]* – There is a strong role of Scotland in manufacturing of the underpinning technologies for quantum computing (especially photonics, nanofabrication). *[QComp1]* – Already there is strong ICT and computer science expertise in the Central Belt, which needs to be integrated as part of any quantum computing programmes. KTN tried to capture this in their UK landscape work when identifying research activities around quantum development involving other disciplines (not just fundamental physics) e.g. computer science, cybersecurity, forensics etc. *[QComp1]* – Evolution is required. Scotland has a good start in hardware and development of machines. Require growth strategy to keep (e.g. photonics) feeding into this.

	[QComp1] – Applications are emerging, with fintech and pharma promising. There have been significant investments but it remains unclear what the 'killer application' will be. *[QComp1]* – We need to get other parts of industry 'up to scratch' on quantum technology applications and how quantum computing can be applied. Effort will be required in education. *[QComp1]* – Net Zero is relevant with quantum applications to existing technology e.g. CMOS and cutting down on energy use. *[QComp1]* – Photonics and silicon interfaces are currently considered to enable quantum computing. There needs to be more education on what is available and how it can be used. *[QComp1]* – The link between quantum computing community and cybersecurity is crucial, and there is a unique opportunity for Scotland to be leader in both domains. *[QComm2]* – Photonics is a clear strength in Scotland. There are all kinds of high level photonics activities in Scotland that are needed for communication systems. Underlying strength in photonics is a real asset. *[QComm2]* – Scotland has a lot of expertise in small start-ups. It is important to look at data in motion, but there is also a huge opportunity for securing static data e.g. implementing quantum random generators but within traditional hardware. *[QS&I3]* – Scotland has strengths in photonics and imaging and along the spectrum from strategic through to applied research. *[QS&I3]* – How do we look for customers? Look for market trends: there was a big shift in technology in OLED (Organic Light Emitting Diodes) and its application in telephones. Special lasers were developed for that purpose. There will be opportunities for designing the next round of lasers for new applications for example for battery technology and medical imaging using quantum technologies. We need to think what customers want and then develop the technology to solve the problem not what technology we have. *[QS&I4]* – Technology clusters are important in innovation. Scotland's Central Belt has industrial and academic strength, which is important for both the UK and Scottish Government. There are opportunities in sensing and imaging which will contribute to resilience as next steps. *[QS&I4]* – Regarding maturity of quantum technologies: we are still a few years away from e.g. someone in a bank using a machine to optimise a portfolio in a few hours rather than few days. *[QS&I4]* – There are opportunities in imaging for healthcare, e.g. disease diagnosis and innovative ways to support NHS. Lasers are already used but what are next steps in adoption of quantum technology?

Skills and workforce	**Summary Session Comments** There are opportunities for job creation across quantum technologies. **Breakout Group Comments** *[QS&I3]* – We need to look at skills and workforce initiatives to fund for Scotland (which is really difficult). We are to some extent already producing graduates, and we have doctoral training centres (a Scottish one, virtual across many universities), but skills and training are not just an issue to be dealt with by universities.
Business models	**Summary Session Comments** The Scottish research community is well known for commercial research. The Fraunhofer Centre is an important example. **Breakout Group Comments** *[QComm2]* – Scotland has a lot of expertise in small start-ups. *[QS&I3]* – Where should we invest? What products should we create? Focussing only on net zero would miss significant other opportunities. It would be hard for us to think only in that context from a commercial standpoint. Quantum at the moment is at the stage of vigorous scientific research to see if markets exist. Example: North American workgroups are seeing big investments (DARPA) with early seeding of the market. Model of the Fraunhofer, invest vigorously. The money from DARPA came with stringent terms (liabilities and clawback). *[QS&I3]* – We need to consider the way the UK programme can develop. The government is a customer and so the community needs to win and develop a programme that the government needs. The ISCF programme invests in the companies to find a niche in the market and government helps to find this. Applications will come from the businesses themselves that the government are supporting them to develop. We (NPL) are a national laboratory keen to work across the UK. *[QS&I3]* – SG could enable a Scottish industry Leadership Group to meet to discuss these issues on a longer term basis. Industry led group with academic partners. *[QS&I3]* – There is potential for early seeding of markets. *[QS&I3]* – There is an offer from the NPL (UK government funded) to work with Scottish companies to build new technologies. They have responsibility for standards and it will be important to have Scottish representation on the new Committee. *[QS&I4]* – Quantum technologies will enable a more resilient, efficient and productive society. The renewable energy sector needs to be engaged, making linkages between the early technology at university scale with companies. There are already projects underway in hydrogen sensing.

Collaborations and networks	**Summary Session Comments** There is a real ecosystem of companies across the system. **Breakout Group Comments** *[QComp1]* – There is an interesting community focusing on quantum opportunities for climate Q4Climate - The union of quantum and climate research *[QComp1]* – How do you build the inward economic focus without limiting open collaboration with others? *[QComp1]* – Scotland is small and there are opportunities to apply quantum technologies in fintech with some activities in progress, working with academics and industry, to connect across UK and wider, engaging businesses, with the intention to apply more widely. There are cross-sector opportunities for application given the presence of sectors in Scotland. *[QS&I3]* – This is not just about academia. *[QS&I3]* – There is a need for 3-way discussion between government, academia and industry. *[QS&I3]* – It is important to consult with industry to identify the opportunities and make the match to academics working in key areas. *[QS&I3]* – There is a huge range of opportunities for quantum technologies. If you want to understand the markets then involve companies that are involved in selling products, which will help inform how academia can be best placed: consult with industry. More discussion is needed with government, academia and industry (all 3 parties around the table). *[QS&I3]* – QED–C in the US is a consortium set up with a mission to enable and grow a robust commercial quantum-based industry and associated supply chain in the United States https://quantumconsortium.org/ *[QS&I4]* – A capability in Scotland is Fraunhofer.

Supply chain resilience and competitiveness	**Summary Session Comments** There is potentially an excellent supply chain strength in Scotland in quantum technologies. Developing the quantum sector will be supported by our supply chains to support jobs and economy, broadly in space and communications. There is broad academic expertise for developing significant export opportunities. **Breakout Group Comments** *[QComp1]* – There are opportunities companies of all sizes (in sectors including finance and manufacturing). *[QComm2]* – There is recognition of supply chain strength in Scotland. Developing the economy will be supported by our supply chains. *[QComm2]* – There is a developing supply chain in lasers for quantum technologies. Fairly large parts of supply chain will involve photonics. *[QComm2]* – Infrastructure providers and the supply chain will make considerable contributions. *[QComm2]* – Scotland already has a lot of broad expertise in the sector. *[QComm2]* – Export opportunities are substantial and global. *[QComm2]* – Are Scotland's strengths exportable? There are strengths in laser technologies, nanomaterials and compound materials, for example. *[QS&I4]* – Gap analysis of the supply chain is worthwhile, for example in developments related to the atomic clock.
Circularity and sustainability	–
Adaptation and transformation	–
Policy and funding	–
Societal issues	–
Infrastructure	–
Communications / Outreach	–

CHALLENGES AND BARRIERS to achieving Scotland's strategic goals	
Technology, research and innovation	**Summary Session Comments** There is a challenge to expand domestic start-ups. **Breakout Group Comments** *[QComp1]* – We need to learn more about where applications for quantum computing will be, to look for new challenges that can be solved on the nearer term scale of a few decades. *[QComp1]* – Quantum computing integration into systems is going to be one of the next big challenges.
Skills and workforce	**Summary Session Comments** There will be skills shortages and so we need to recruit and retain. School leavers need to be aware of the attraction of quantum industries as this will become essential to achieve our goals. **Breakout Group Comments** *[QComm2]* – A key and common theme was skills shortages in the sector and the need to attract people to a huge challenge that needs addressed. *[QComm2]* – We need to create opportunities for universities to resolve this. The issue is at all levels (technician to PhD), and the messaging (of the opportunities in this sector) needs to reach out into schools. *[QComm2]* – We need the skilled people to do the work. There is the risk 'brain drain' across companies. This is a potential challenge. *[QComm2]* – We need 'suitably qualified experts' (the terms used by UK Government to describe the resource gap). Countries who win are the ones who get expert people trained and into companies. Getting the next generation of trained people is key. High quality jobs can be created but we need people aspiring to join this industry. **RECOMMENDATION** – In quantum computing, the common thread of discussion is that Scottish Government and agencies can do more and need to look at this issue. *[QComm2]* – There is ambition in the sector but we need to attract people. Central Scotland is a key cluster area but we need to consolidate this success. Success breeds success. *[QS&I4]* – We need training opportunities for young people in quantum at all level from school through to university. There is great demand for physics PhD graduates. *[QS&I4]* – We need to attract more talent into Scotland for quantum positions, build up the interest. *[QS&I4]* – We need to retain PhD students in Scotland after graduation, and to attract students to science and engineering in general. Centres for Doctoral training support this.

Business models	**Summary Session Comments** We should learn from other models e.g. Fraunhofer; DARPA. **Breakout Group Comments** *[QComm2]* – It is about having the traditional markets open to trying new technologies. Companies need to grow in scale and be able to export. Initiatives that would support SMEs in achieving those objectives would be useful. *[QComm2]* – There are relevant links to Logan Review. Start-ups are critical to economic recovery. Financial support is needed to establish and support key challenges and critical for future prosperity. *[QS&I3]* – There are opportunities to learn (positives and negatives) from existing models such as Fraunhofer, DARPA in the US (noting terms of their contracts including the power to claw back funding in the event of failure). *[QS&I4]* – A barrier is that most of the funding for the UK Quantum Technology Programme is already spent. We need a clear understanding that the journey is still underway. A firmer long-term commitment is needed to see future economic benefit.
Collaborations and networks	**Summary Session Comments** There is a challenge in connecting different communities, some of whom have less awareness of what's happening in quantum. We need to get more people talking within the different groups. The relative roles of academia and industry need to be understood. We should consider setting up a version of the UK Quantum Technologies Programme in Scotland. Scottish Government should develop a leadership group. Understanding different skill sets and bringing them together is important. **Breakout Group Comments** *[QComp1]* – Need greater interaction with end-users to explore what current problems there are and the timescales businesses are looking for solutions in. *[QS&I3]* – We should involve the Innovation Centres. They were set up to identify opportunities to benefit the economy from research. Technology Scotland has a Photonics Network

Supply chain resilience and competitiveness	**Summary Session Comments** Scalability of compact devices is a challenge/opportunity. It would be easy to oversell quantum computing and how it helps to achieve strategic goals. We need to develop awareness of what is readily available now and to bear in mind limitations. **Breakout Group Comments** *[QComm2]* – We would support specific support for Scottish owned and based quantum companies and the key role of start-ups. *[QComm2]* – Investment is needed by Scottish owned companies, especially start-ups.
Circularity and sustainability	–
Adaptation and transformation	–
Policy and funding	**Summary Session Comments** Policy awareness: policy makers need greater awareness and strategy implementation will need more collaboration. **Breakout Group Comments** *[QComp1]* – Educating policy makers on this technology is a challenge. *[QComp1]* – Developing Scottish Government strategy for quantum technologies will require a a 'horizontal infrastructure' because of its impact across very different policy areas.
Societal issues	–
Infrastructure	**Summary Session Comments** To develop Net Zero will need appropriate data infrastructure, with secure data infrastructure being key. Quantum technology will secure communications, which will secure national infrastructure.

Communications / Outreach	**Summary Session Comments** Need quantum technologies to be defined and communicated in a way that is useful to the wider non-specialist audience / end-users, with clarification and communication on Quantum 1.0 and Quantum 2.0, and what the transition will involve. Clear communications are viatl. Ministers need to understand what technology can do, what Scotland's strengths are and then help the sector via e.g. Scottish Development International (SDI). We should not confuse the basis of different quantum technologies with the applications they potentially enable. **Breakout Group Comments** *[QComm2]* – Investment is needed in Scottish owned companies, especially start-ups. Also a concern is that end users need to be helped to see Scottish Start-ups. Investors need to be become aware of the strengths of Scotland's quantum scene globally.

INTERVENTIONS AND SUPPORT MECHANISMS required to support delivery of Scotland's strategic goals	
Technology, research and innovation	**Summary Session Comments** We should look at market trends, e.g. lasers in healthcare. Some technologies are not yet sufficiently mature. We need a sufficiently long planning horizon. We need a manufacturing base close to end users. Training, the planning horizon and the need to accelerate translation are all important.
Skills and workforce	**Summary Session Comments** More training opportunities need to be provided. We need to develop a national message for the quantum sector to develop the pipeline of training skills; support mechanisms will be required. We need a national message on the value of quantum technologies from the perspective of an employer and a pipeline of skills and people for our growing quantum sector. Seconding people between parts of the quantum sector will improve mobility. The retention of talent and need for training at all levels (not just senior) is needed. Skills are needed in manufacturing and engineering to enable scale up. There will be skills shortages: there is a need to train, attract, and retain people with the right skills. Skills coordination must be developed in a sustainable way, perhaps engaging a leadership group.

	Breakout Group Comments *[QComp1]* – We should train students and create a workforce. *[QComm2]* – Secondments for professionals would help. *[QComm2]* – Skills are needed to drive the technology forward. *[QS&I3]* – Funding apprenticeships into businesses would be helpful. *[QS&I4]* – Skills are needed in manufacturing/engineering to accelerate uptake of technologies. We need further funding tailored to the interface between academia and industry.
Business models	**Summary Session Comments** Investment is needed and investors need to be more aware of the strength of Scotland's quantum scene globally. Public intervention: public funding received is not being translated into commercial opportunities. **Breakout Group Comments** *[QS&I3]* – There is a need for long-term commitment from Government to specific sectors. *[QS&I3]* – Infrastructure investment in Scotland could be a big enabler. Quantum network capability in Scotland is connected to other parts in UK but there is not a direct connection in Glasgow and Edinburgh on fibre or satellite communications and the space network. Scotland investment in engaging the communications infrastructure sector would be helpful. *[QS&I3]* – As quantum technology matures, standards will become more important and new committees on standards will help drive the technology and applications. It is important to have representation on these committees (both Scotland and UK in general). *[QS&I3]* – Technology Scotland have a special interest group (SIG) in quantum.
Collaborations and networks	**Summary Session Comments** Need stronger connection between people in different sectors / quantum, and end users. Need academia, industry and the public sector to talk to one another. Cluster needs to continue to grow. Scotland's photonics cluster is recognised by other countries. Cross-sectoral collaboration is key, not just academia and industry, but investors too. Sharing of knowledge across UK is crucial. It's vital to encourage academic excellence to thrive, and to encourage collaboration.

	Breakout Group Comments *[QComp1]* – Connecting people: it takes a long time to get people together, cross-ICT programmes have been successful in this. *[QComp1]* –We need to ensure end users from other sectors are brought in to the discussion. *[QComp1]* – We need to bring in other funding initiatives which make end users speak to developers, to bridge the gap. *[QComp1]* – There is funding for projects but there is work to be done in educating both researchers and end users before we get to the projects stage. It would be helpful to have new mechanisms to build relationships with end users, bidirectional education, learning about problems and working back and forth on medium-term solutions. *[QComp1]* – There is broad expertise in quantum computing across Scotland, and strong fintech, photonics and pharma sectors. We need a mechanism to facilitate and build relationships. This must be done on a national level and to be seen in the bigger context to maximise opportunities. *[QS&I3]* – Infrastructure investment would be an enabler e.g. in a quantum communications network linking Glasgow and Edinburgh *[QS&I3]* – Would there be any interest and value in Scottish Government enabling a Scottish industry Group to meet together to discuss these issues on a longer term basis i.e. industry led group for industry with academic partners? UK Quantum: there may be great value in having a specific Scottish version of that with some national bodies wanting to have a more Scottish focus to consider various schemes for collaboration and other subjects. International standards in quantum technology will be important. See for example: QED-C | The Quantum Economic Development Consortium (quantumconsortium.org) https://quantumconsortium.org/
Supply chain resilience and competitiveness	**Breakout Group Comments** *[QS&I3]* – Infrastructure investment would be an enabler e.g. in a quantum communications network linking Glasgow and Edinburgh.
Circularity and sustainability	–
Adaptation and transformation	**Summary Session Comments** Need to find applications that are 'out of the usual'.

Policy and funding	**Summary Session Comments** Foreign Direct Investment (FDI) is important. Planning horizon: quantum has such significance in the policy and technology world but there is still a way to go in making sure we have a shared view of the planning horizon. Whilst focus is on Scotland, the Scottish funding and policy landscape must be considered in the context of the wider UK (and international) funding and policy landscape. There has been a significant level of progress in Scotland and Scotland is performing well in quantum, although supported by the UK context. SFC also supported Quantic (the Quantum Technology Hub in imaging, led by the University of Glasgow) in UK programmes in 2014; investment from SFC can give Scotland a competitive edge in UK competitions. **Breakout Group Comments** *[QS&I4]* – For the amount of R&D investment Scotland is able to attract, we are still not translating this into commercial solutions fast enough. We need the Scottish Government to use policy and investment to change the environment.
Societal issues	–
Infrastructure	–
Communications / Outreach	**Summary Session Comments** We need a clear recognition that this is an important journey, but it's still underway. **Breakout Group Comments** *[QComm2]* – Much messaging does not reach young children. There is not enough awareness amongst the young about technology manufacturing in Scotland.

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