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A Finmeccanica Company

Quantum Technology Challenges for Defence

Turing Gateway to Mathematics
Isaac Newton Institute for Mathematics
Cambridge University - August 2014

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Selex ES Limited

Selex ES Limited in the UK – Who we are.

In 2012 our UK business:

Revenue:	£1.08 Bn
Sales in UK	£410.9M
Export Sales	£671.2M
R&D	£142.9M
(of which PV	£47.0M)

Selex ES global footprint:

- Over 70 international customers
- Sites: UK, Italy, USA, KSA, Brazil, UAE, Germany
- Over 17,000 employees world wide
- €3.5 billion revenues
- 12% investment in R&D

4,711 people

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Selex ES – How we organise our capabilities

Airborne and Space Systems Division

- Airborne radar
- Electronic warfare systems
- EO/IR & Laser systems
- Integrated mission systems and sensors
- Airborne surveillance systems
- Tactical UAS
- Space sensors and equipment

Land and Naval Systems Division

- Integrated land and naval command and control systems
- Land and naval radar
- Electro-optical sensors
- Tactical communication systems
- Battlefield protection systems

Security and Smart Systems Division

- Homeland and critical infrastructures' security architectures
- Cyber and secure communications systems
- Information management and automation systems
- Airport systems
- Air traffic and vessel management control systems

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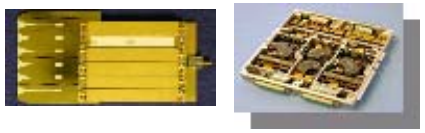
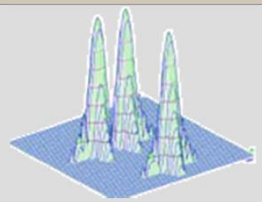
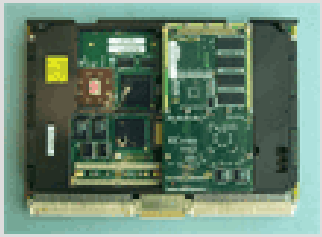
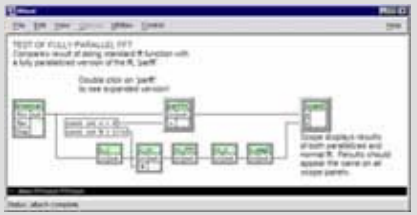
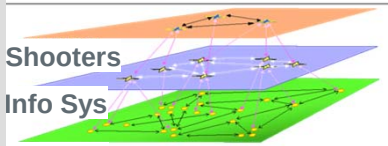
Our Real-world Sensing Technologies

Signal & Data Processing is UBIQUITOUS across all we do in our multi-spectral sensing domains

Real World Signal	Signal Processing & Sensing Technology	Digital processing & Information Management	Effector Technology	Applications
Radio Frequency				Fire control and surveillance radars
Electro Optic				Targeting missiles and surveillance systems
Electronic Warfare				Integrated defensive aids systems
Acoustic & Motion				Artillery pointing and battlefield navigation
Networking, Comms & CYBER	Networking Methodologies			Networked sensors Tactical data networks Data-links Management systems

Shooters
Info Sys
Sensors

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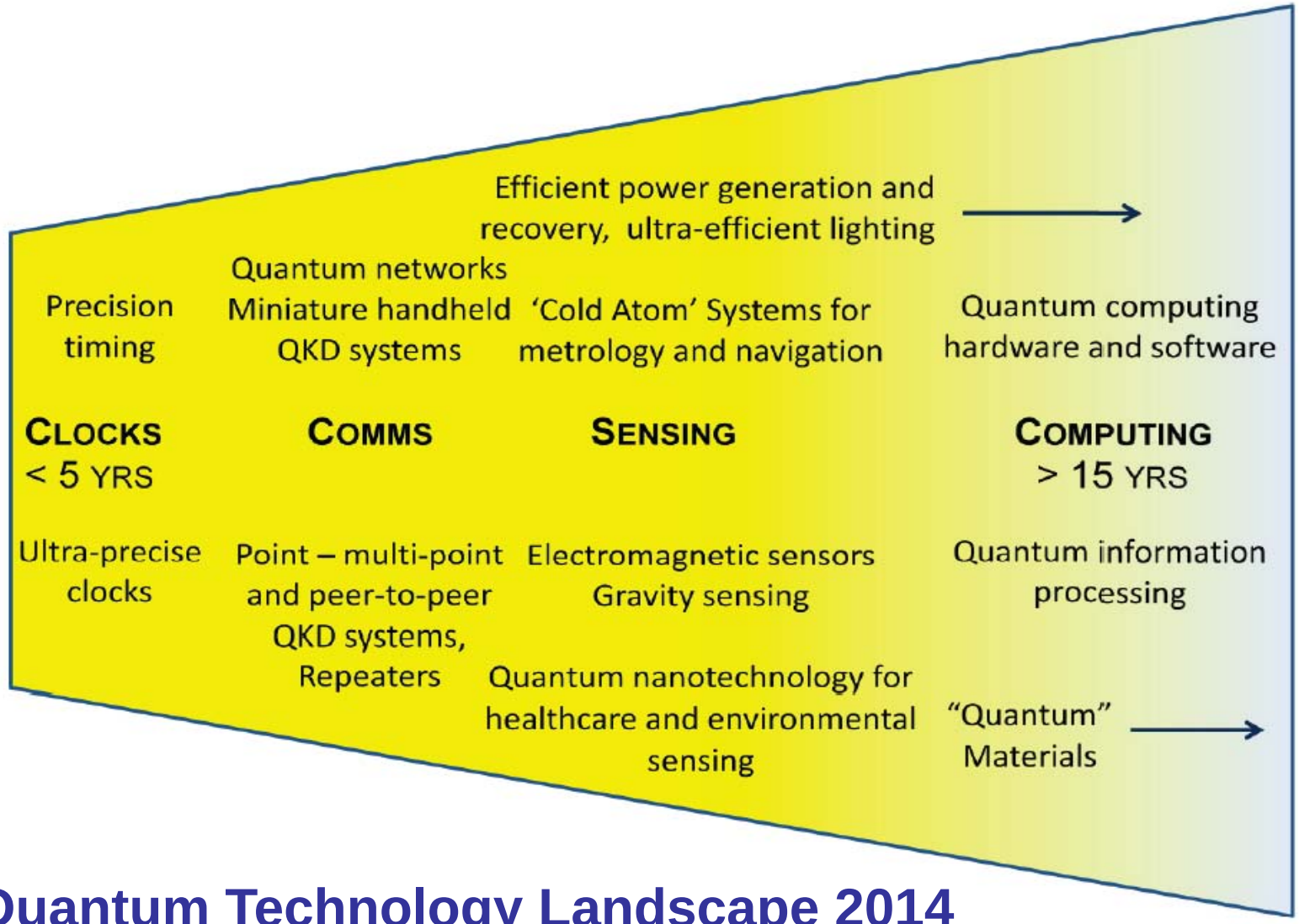
Quantum Technology Challenges for Defence

- Within the UK Defence Community Quantum Technologies are viewed as a key area for providing new and innovative capabilities for our forces.
- Opportunities to exploit Quantum Technologies within Defence exist in:
  - Sensing Domain– Quantum technology may open up new sensing domains that enable the direct measurement of phenomena that today we can't measure such single molecule detection, atmospheric effects, time resolved photo-luminescence and improved imaging through turbulence etc.
  - Navigation Domain - Where innovations such as the Quantum Compass (NPL and Imperial) may offer a more resilient navigation solution than the ubiquitous GPS.
  - Precision Timing Domain – Again a Quantum approach removes our current reliance on susceptible GPS solutions and like GPS a future Quantum based precision timing solution could also include accurate Navigation functionality to support operation in GPS denied environments.
  - Computing Domain – Quantum computers may easily solve problems that today's computers struggle with such as breaking difficult cryptographic ciphers.
  - Quantum Materials -
- Each of these Quantum Technology opportunities has it's own unique mathematical challenges that must be understood before the technology can be widely exploited.

Quantum Technology Challenges for Defence



UK Quantum Technology Landscape 2014

(See DSTL/Pub75620 - Final Version dated 14/02/2014)

Practical Quantum Sensing Challenges

- Quantum sensors are devices that exploit quantum correlations such as quantum entanglement to enhance performance over that of the more classical system approaches. The use of entangled photon pairs may provide benefits where imaging through turbulence, where the question arises whether Ghost Imaging (GI) and/or Quantum Imaging (QI) has a practical use in long range imaging (>1km) through turbulence.

- The problem is usually transformed into the measurement of correlated photon pairs in which "entanglement" is derived from the generation of photon pairs through parametric down conversion. producing temporally and spatially correlated pairs with temporal decorrelation, dt, setting the range and spatial decorrelation, dx.
  - Can dt and dx be improved using entangled photons rather than classical correlation?
  - Can this improvement be sustained through turbulence over a long range where the round trip time delay is ~1ms? The bandwidth for turbulence is 100-1000Hz.
  - Can higher order entanglement (3, 4, 5 etc. photons) increase temporal and spatial resolution through turbulence beyond classical limits?

Selex ES POC here is Prof Rob Lamb (robert.lamb@selex-es.com)

Navigation & Precision Timing Challenges

- Here the need is for resilient and accurate chip-scale navigation and precision timing solution in a GPS denied environment. Mature Technology solutions are becoming available, but US ITAR rules will impact the ability of UK Industry to exploit these in the export domain and hence there is a need to mature non-US Quantum technology based solutions.
  - Challenges for the maturation on Quantum technologies in the precision timing domain include susceptibility to stray magnetic or electric fields, vibration, shock and temperature together with the independent observation of acceleration and angular rate. With the push toward smaller chip-scale solutions there is a clearly need for better modelling and methods for the calibration for these effects.
  - Quantum Clock Synchronisation between large numbers of clocks – issues include compensation for relativistic effects, and non-Newtonian frames of reference, - what does simultaneity mean when clocks at different positions and relative velocities inherently run at different rates? . Links also to gravimetric sensing and effects.
  - Quantum technologies also enable the implementation of more capable gravitational sensing instruments, such devices may offer new opportunities for higher performance geo-location systems.

Quantum Computing Challenges

- Here the need is for high performance computing to meet the challenges of processing the large sensor data sets that we see on todays Battlespace.

- Quantum technologies may well offer novel ways to combine / process such multidimensional datasets that are essentially intractable with traditional Von Neumann computer architectures.
    - Challenges also exist for the mapping of current data and information analytic algorithms onto future quantum computer platforms.
    - Another challenge here is providing the 'human in the loop' with an intelligible/ understandable rationale for the information that is being provided – particularly where that human may be required to make decisions that involve the deployment of weapons.

- Quantum Processing solutions are becoming available but there is a tendency to design these solutions around specific problem types (e.g. simulated annealing problem set that seems to be well matched to the D-WAVE processor).

Quantum Material Challenges - Inorganics

- Modelling and designing quantum based materials and structures that do not (readily) appear in nature - atomic level quantum engineering – predicting materials parameters such as band-gaps, electron mobility, detectivity, absorption spectra, thermal characteristics etc.

- Device Physics Modelling for Atomic scale engineered meta-materials and Nano-materials - understanding how the quantum interactions at materials level impact, influence and control the overall device behaviours and performance.

- Potential defence end user applications could include
  - Improved IR and wide band sensors,
  - Improved RF receivers front ends, eg better spectrum congestion capability, dynamic range
  - Better power generation/handling devices
  - Lower power utilization – (e.g. reducing the burden on the soldier)

Quantum Material Challenges – Bio-organics

- Quantum mechanics has been shown to play a fundamental role in a number of important biological systems, and a number of theoretical papers and experimental confirmations on the role of quantum coherence in biological processes have been published.

- Math challenge is to develop techniques for modelling and analysing complex bio-systems / molecular structures that use for example quantum coherence
  - Non trivial issue is that such bioorganic systems are typically complex and hierarchical e.g. the form of the photosynthetic complex comprises tens of thousands of atoms arranged in hierarchical molecular groupings/structures.

- Other bio-systems exhibiting potential quantum coherence influence include
  - The avian compass (entangled free radical pairs in biomolecules exhibit enhanced sensitivity to weak magnetic field).
  - Sense of smell (phonon-assisted electron tunnelling provides enhanced discrimination between different scents)

Long term objective would be a formalism to allow one to the state space of bio-organic systems and their dynamics in quantum mechanical terms

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Selex ES views our collaborations with Academia as being essential to our business and beneficial to all those involved.

Questions ?

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