Getting there

In our editorial in the April 2007 issue of *Nature Physics* we looked at the claim of the first demonstration of a commercial quantum computer — D-Wave's 16-qubit Orion. Eight years later, we ponder whether quantum technologies have really become commercial.

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Browse any science news outlet and you'll be bombarded with claims of spooky quantum effects being harnessed for technological applications. The uninformed reader might get the impression we are weeks away from having quantum processors in our phones and quantum navigation in our cars. But in reality things are a little different: we are far from reaching even medium-scale commercialization. And one might legitimately wonder whether a market for quantum technologies actually exists.

D-Wave — the first (and only) company to sell quantum computers — was founded in 1999, and quantum cryptography companies like MagiQ or ID Quantique were launched around the same time. Other established companies — including Toshiba, Hitachi, NEC and IBM — began investing in quantum computing and quantum cryptography research programmes. Some projects were abandoned while others, like Toshiba's quantum key distribution (QKD) system, flourished. Since then a few small quantum cryptography companies have appeared, enjoying varying degrees of success.

Despite this investment, and years of research into developing new quantum algorithms, only a few strong contenders have emerged on the list of practical applications: quantum machine learning and quantum simulation techniques including quantum chemistry calculations. Whereas the latter is probably of interest only to academia and perhaps for ambitious R&D in materials and pharmaceuticals, the former promises a speed-up in clustering, classification, and pattern-finding algorithms, which resonates with another recent hot topic: big data.

D-Wave supplied its products to high-profile customers, including Lockheed Martin, Google and NASA, something that many took as an indication of commercial potential. And when Google and NASA created the Quantum Artificial Intelligence Lab, quantum machine learning shifted into the spotlight. But is it really the next big thing? In a Commentary on page 291 of this issue, Scott Aaronson critically examines the prospects and caveats of quantum machine learning. Although developments in this area are undoubtedly exciting, he cautions that the real speed-up comes subject to certain conditions — so it is essential to consider the details carefully.

The first QKD-protected bank transfer was demonstrated in Vienna in 2004, and quantum cryptography was used in the Swiss elections in 2007. But despite these early promises — as well as more recent advances — the technology has not yet attracted a critical mass of commercial interest. To put it bluntly, your local internet provider is unlikely to invest in quantum cryptographic solutions, at least for the time being.

But what about other quantum technologies? Writing on page 293, Jürgen Stuhler provides an industry perspective on the commercialization of quantum optics in particular, and quantum technologies in general. He points out that although impressive advances have been made with atomic clocks and quantum-technology-enabled sensors, the gap between laboratory demonstrations and market products is still significant.

So what are the bottlenecks to the commercialization of quantum technologies? Anas Al Natsheh and colleagues have recently analysed the challenges in commercializing high technologies with a case study on QKD (*Technol. Innov. Manag. Rev.* **5** (1), 26–36; 2015). They identify the main factors, which are most likely applicable to quantum technologies in general, as "scattered and small markets, supply chain development, technology validation/certification, a lack of available or adequate infrastructure, and after-sales services". The first is probably the most obvious and problematic issue: with no real threat to the traditional cryptographic systems, there is little drive towards investing in alternative technologies. How to address the other issues is another complicated matter that might be approached, as Stuhler suggests, by well-directed governmental funding.

Research into quantum technologies has undoubtedly made huge progress over the past decade both on the fundamental and applied fronts, but instead of becoming more focused it has branched into many directions. Whereas this spread is great for boosting scientific advance, it might not be ideal for delivering commercial products on a short timescale. The 2004 DARPA Quantum Computation Roadmap (http://qist.lanl.gov/qcomp_map.shtml) has not been updated in more than ten years. Perhaps one way to deal with the obstacles on the road to the commercialization of quantum technologies is to take an approach inspired by engineering: to focus on a clear goal and design realistic steps towards achieving it. ❐