1980s aircraft helps quantum technology take flight

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What does a 1980s experimental aircraft have to do with state-of-the art quantum technology? Lots, as shown by new research from the Quantum Control Laboratory at the University of Sydney, and published in *Nature Physics* today.

Over several years a team of scientists has taken inspiration from aerospace research and development programs to make unusually shaped experimental aircraft fly.

"It always amazed me that the X-29, an American airplane that was designed like a dart being thrown backwards, was able to fly. Achieving this, in 1984, came through major advances in a discipline called control engineering that were able to stabilise the airplane," said Associate Professor Michael Biercuk, from the School of Physics and director of the Quantum Control Laboratory.

"We became interested in how similar concepts could play a role in bringing quantum technologies to reality. If control engineering can turn an unstable dart into a high-performance fighter jet, it's pretty amazing to think what it can do for next-generation quantum technologies."

The result is that the researchers have been able to turn fragile quantum systems into useful pieces of advanced technology useful for everything from computation and communications to building specialised sensors for industry. The trick was figuring out how to protect them from their environments using control theory.

The big challenge facing quantum technologies is they are very sensitive to random 'noise' in surrounding environments, said Associate Professor Biercuk. "Noise, in this case, is a bit like local electromagnetic weather experienced by a piece of hardware. Imagine your television only worked when the weather was perfectly sunny. Something needs to be done to make that technology more functional, even on the grey days."

The new field of quantum control engineering provided a path forward. The first step was trying to pinpoint how noise would affect a quantum system while it performed some task, which is fiendishly difficult.

"We were able to calculate how much damage is done to a quantum state using so-called transfer functions tailored to specific operations - for instance, manipulating a quantum system as a part of a computation," according to co-lead author, PhD student Harrison Ball.

The next issue was to show that the theoretical techniques actually worked.

"One of our main achievements has been to show - using experiments on real quantum systems in the form of atoms in a special trap - that the transfer functions were excellent at predicting how quantum systems changed in response to environmental noise."

With new capabilities to predict the effect of the environment on quantum systems, it became possible to protect them by applying the right control techniques.

"Similar to the control system that kept an aerodynamically unstable plane aloft, experiments revealed that our new techniques were able to keep the atoms performing useful computations," said Biercuk. "Turn off the new control techniques and they would crash and burn."

"Achieving this is a grand challenge for the entire community," according to Ball, and it is especially important as researchers move from proof-of-principle demonstrations to trying to develop real quantum technologies.

Working to make those technologies a reality is the aim of Associate Professor Biercuk and his colleagues in the ARC Centre for Engineered Quantum Systems.

"This may sound like futuristic fantasy, but the navigation system in your car works because of an early quantum technology - atomic clocks," according to Biercuk.

"We know that exotic phenomena like quantum systems being in two places at once, and even the ability to teleport quantum states, are real and accessible in the laboratory. Now we are trying to actually put them to work, and that means figuring out how to coax quantum systems into doing new and useful things."

More information: "Experimental noise filtering by quantum control." *Nature Physics* (2014) DOI: 10.1038/nphys3115

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