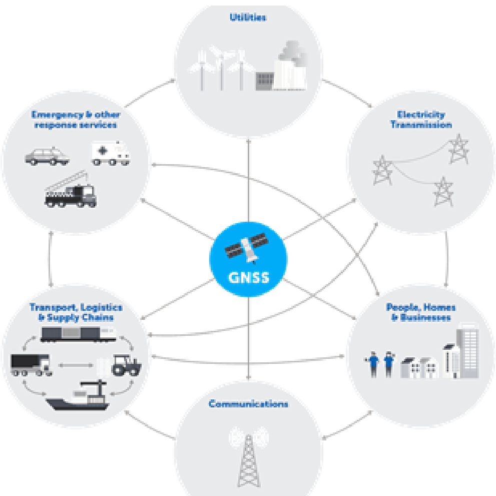
SMARTSAT
COOPERATIVE RESEARCH CENTRE

Compact Clock for Small Satellite Applications

Building a sovereign satellite navigation capability for Australia

Mission Goal: The development of space-qualified, compact clocks and optical time transfer, contributing to an alternate Positioning, Navigation and Timing capability for Australia.

Ubiquitous and reliable availability of precision time is of vital importance to our modern society. Its most high-profile application is seen in daily use by most of the world's population though Global Navigation Satellite Systems (GNSS) such as the United States' Global Positioning System (GPS) or the European Union's Galileo system. Collectively, these GNSS generate trillions of dollars of economic benefits every year around the globe. However, all GNSS are potentially subject to spoofing, jamming or unavailability for a myriad of human and environmental reasons. Further, Australia lacks a sovereign GNSS which represents an additional vulnerability of a critical system on which we are all dependent.



Other emergent space-based applications for precision timing are seen in applications where highly accurate satellite position and timing information may be required. Such information is crucial for intelligent space systems that use multiple sensors and platforms to provide high performance monitoring of Earth or Space at low cost.

This project is addressing one of the key hurdles to achieving an alternate Positioning, Navigation and Timing (PNT) capability for Australia through the development of space-qualified, compact clocks. Over the last 5 years, the University of Adelaide has been developing a new optical atomic clock technology that uses small glass cells containing specially prepared atomic gases to produce a high-quality timing signal. Conventional space atomic clock technology makes use of similar technology; however, the University of Adelaide team took a revolutionary step in which they exploit an exceedingly narrow optical resonance of those atoms to create the timing signal. Conventional approaches make use of much lower frequency microwave resonances in those atoms. The optical approach allows significant reductions in size and weight, while opening avenues to higher performance.

The University of Adelaide team has already demonstrated timing stabilities comparable to the very best GNSS clocks (the Galileo H-maser) in a system that is at Technology Readiness Level (TRL) 4. Excitingly, a technical pathway has been identified to improve this performance by 10-fold whilst at the same time reducing size, weight and power metrics.

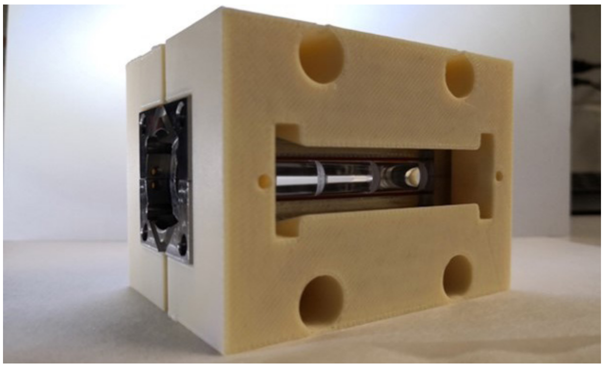
The goal of this project is to demonstrate clock technology that is suited to satellite deployment, but which has an order of magnitude higher performance over clocks that are currently used onboard satellites.

IN COLLABORATION WITH:

THE UNIVERSITY of ADELAIDE

QUANTX LABS

This project will mature the Compact Clock technology to the point where it can be developed into an Engineering Model in a second phase suitable for functional testing and space qualification of components. To make the clock more suitable for space-based applications, the high-power consumption and heavy components need to be replaced with small, low-power alternatives. Under this project, a new laser interrogation and detection system will be built, while the physics package will be completely replaced. Much of the existing electronics will be replaced with compact digital versions.

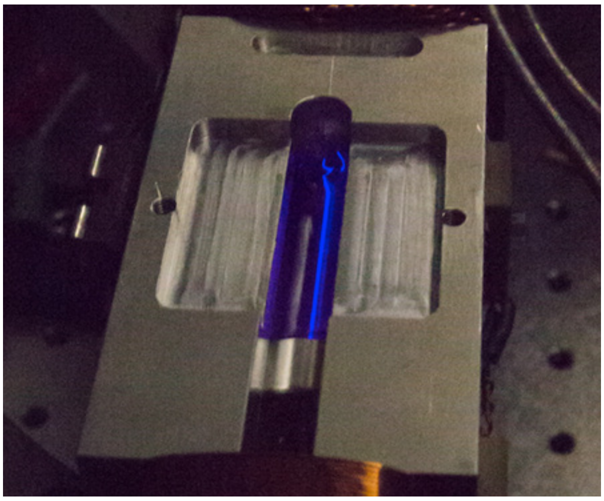


The Atomic Cell sub-assembly (above) is filled with Rubidium (Rb) Vapour and temperature controlled. Two optical beams from the Laser sub-assembly (not shown) are directed through the Atomic Cell, interacting with the vapour. A Frequency Stabilisation sub-assembly controls the frequency of the lasers to maintain a stable lock to the Rb atomic transition. The stability-over-time of the output clock frequency is dependent on the precise measurement and control loop. The timing performance will be measured against world class frequency standards as well as QuantX Labs' Cryogenic Sapphire Oscillators.

Compared to the clocks that are currently used in GNSS, the clock to be developed under this project has many advantages:

1. Timing stability that will be 10-times better than the current best GNSS – achieved by using an optical transition that allows for much greater frequency stabilities to be achieved.
2. Technologically simple which will make a final product robust and reliable - does not require laser-cooled cold atoms.
3. All fibre-based 'commercial off-the-shelf' components - components are robust and reliable as they have taken advantage of the engineering and technologies developed by the telecommunications industry.

The Adelaide clock makes use of a novel, two-photon transition producing very narrow linewidths for a thermal vapour. The enhanced performance is achieved by exciting the atoms with two different colour lasers at 780nm and 776nm, yielding a 100-thousand-fold increase in signal-to-noise over traditional approaches. The clock uses the blue emission of 420nm fluorescence as an error signal to keep the lasers locked to the atomic transition.



Precision timing is of vital importance to our modern society and is utilised by everyone daily though the Global Navigation Satellite Systems, such as GPS, which generates trillions of dollars each year in economic benefits around the globe. High precision timing is an underlying technology for distributed systems and systems resilience. As such, it can feed into a multitude of different technologies being developed by, or that are of interest to, SmartSat. Australian Department of Defence sees potential for the clock technology to be demonstrated through the Resilient Multi-mission Space STaR Shot missions in order to evaluate its performance in space. If successful, the project may contribute to the goals of the Defence Resilient Multi-Mission Space STaR Shot through provision of technology that can demonstrate accurate and resilient timing for advanced small satellite concepts potentially leading to incorporated in more advanced constellation demonstration of enhanced resilient space services.

Other potential application areas are being uncovered through a separate SmartSat project (P2-21).

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