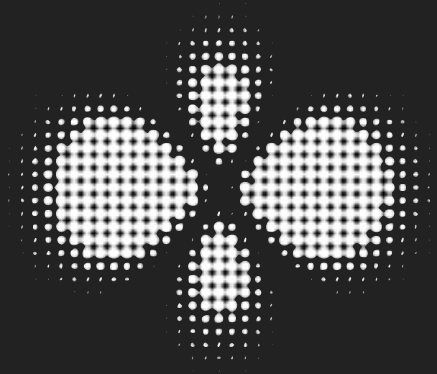


TWIN PARADOX LABS

SURREY SPACE CENTRE

CEOI Emerging Technologies Workshop - April '21

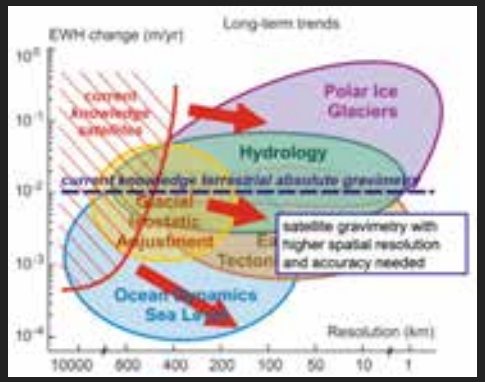
Dr P. B. R. Nisbet-Jones, Dr C.P Bridges

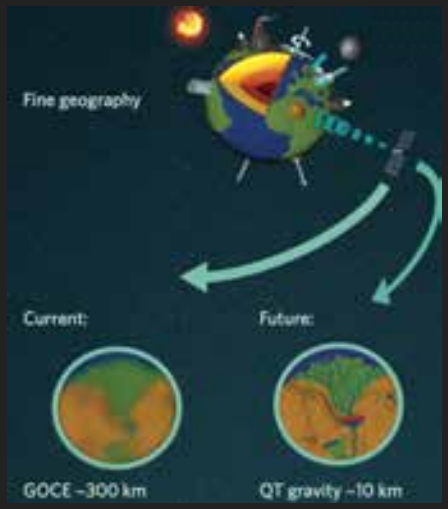
LEGO

LASERS FOR EARTH GRAVITATION OBSERVATION

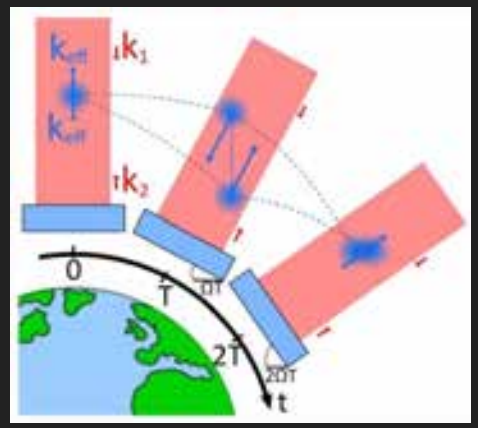
WHY?

- Gravimeters for EO
  - Laser Ranging (e.g. GRACE)
  - Atom interferometer (AI)
  - Relativistic - atomic clocks
- AI & relativistic not yet in space
- Laser ranging cubesats?
- Laser TRL is a major issue

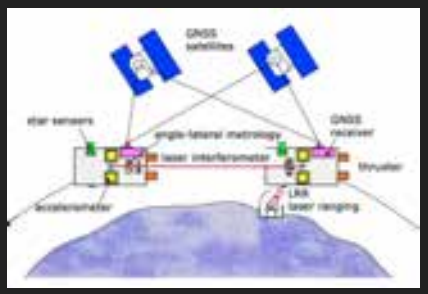




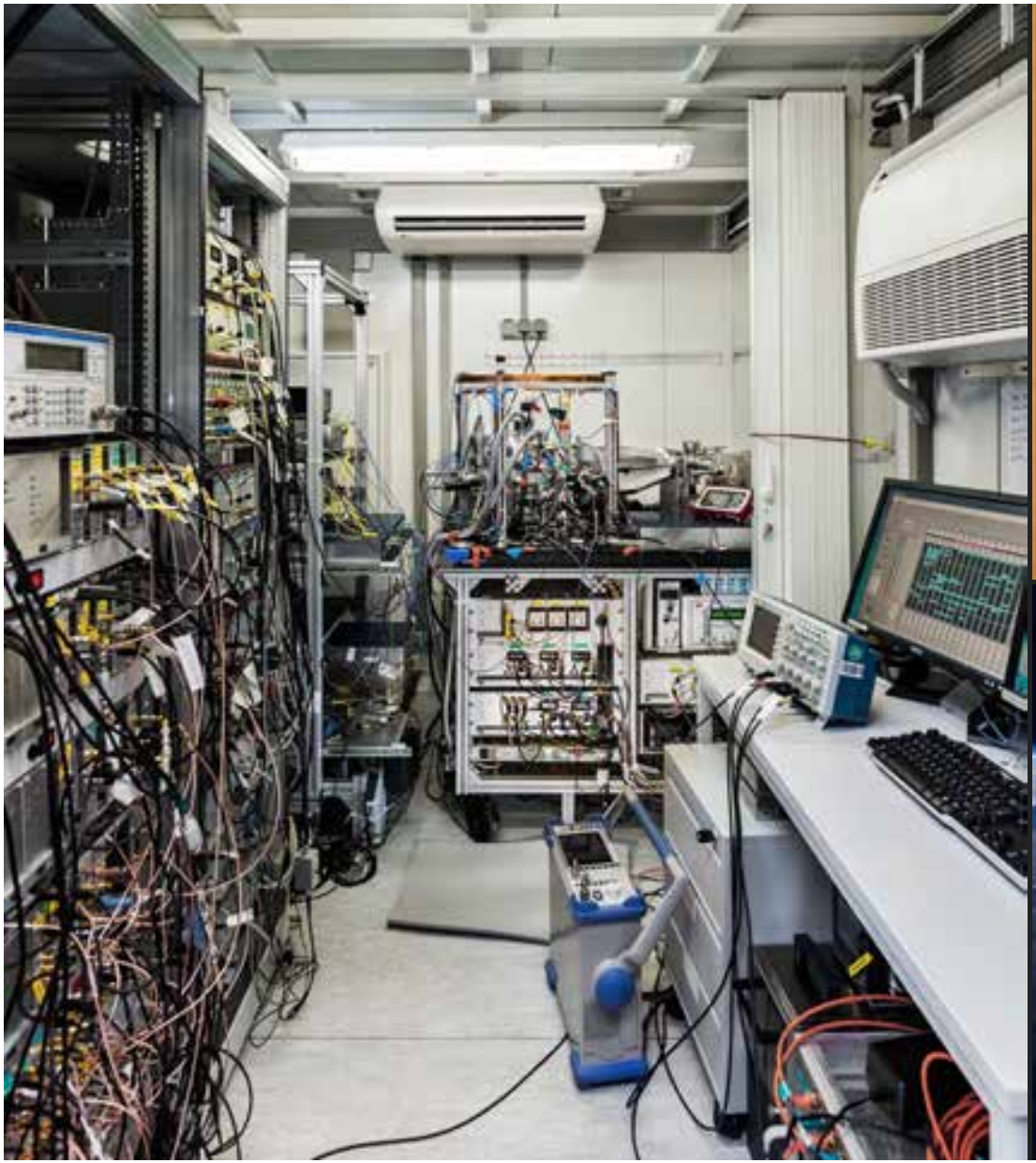
Bongs, Nat.Phys 11 615 (2015)

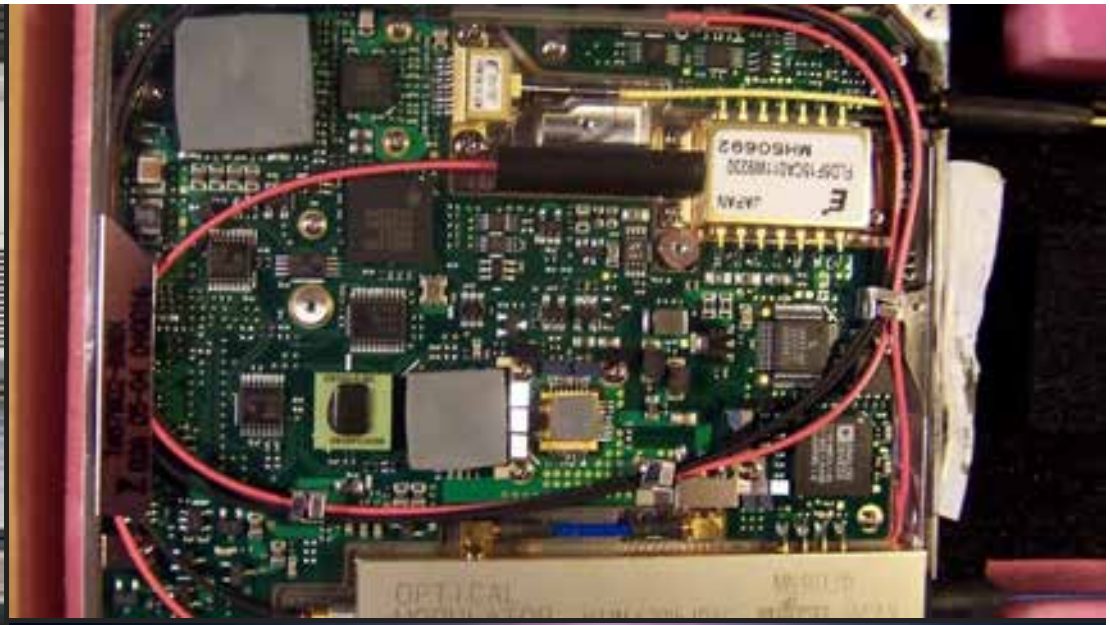


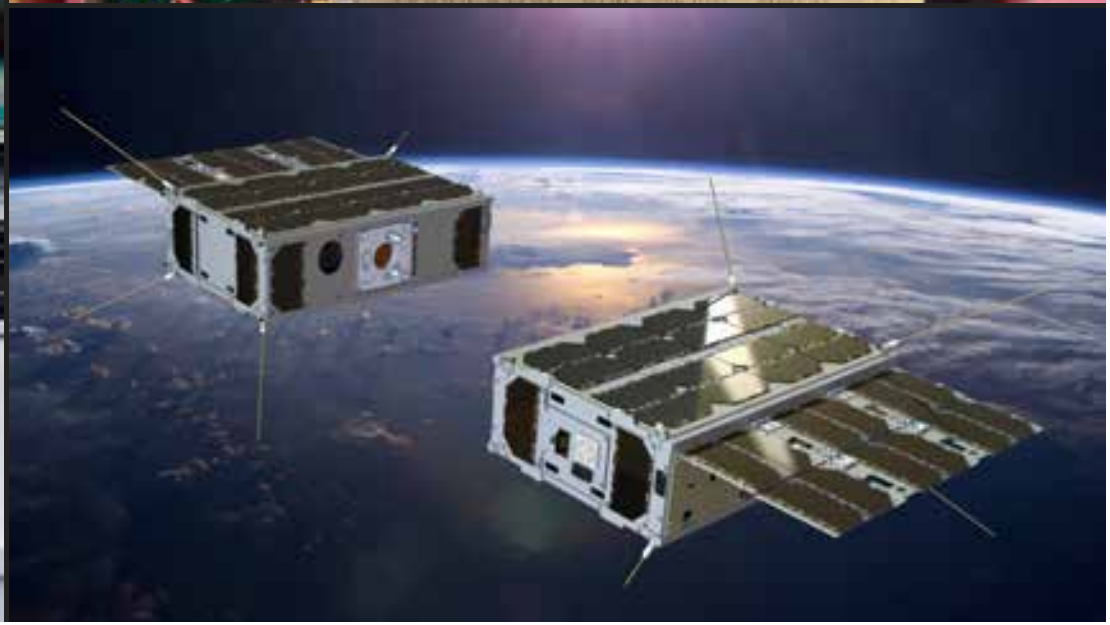
CAL - ISS



ESA: NGGM







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PROJECT OBJECTIVES

Science

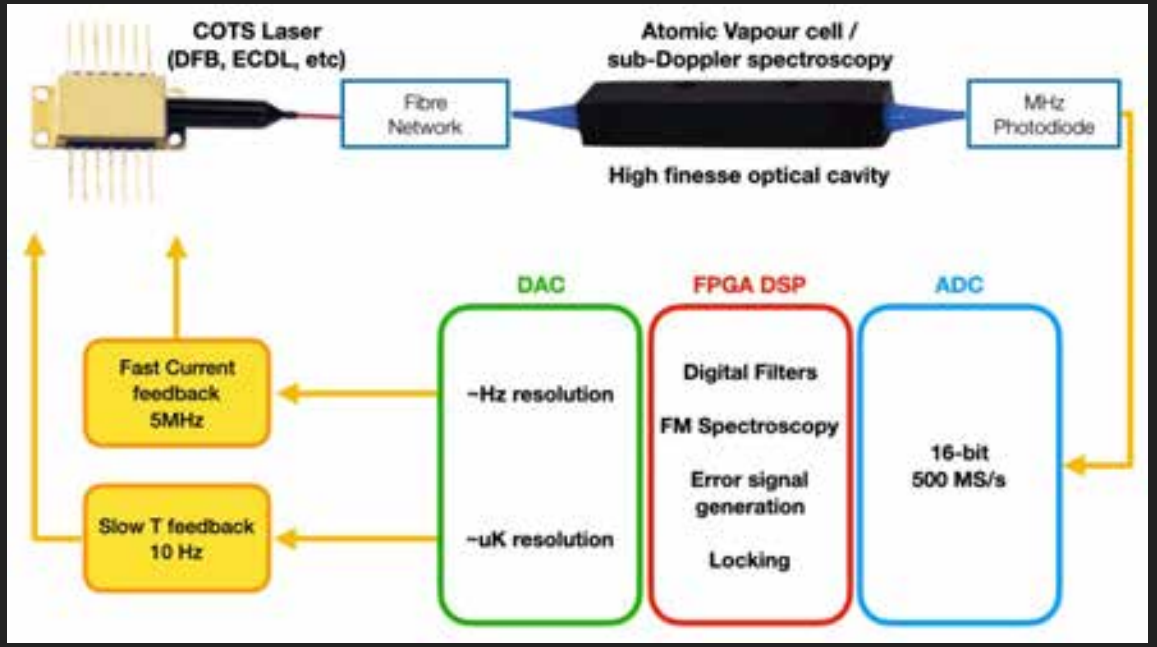
- Build a stabilised laser for a Gravimeter / Quantum sensor
  - Use 780nm Rb stabilised laser: Prove 10 kHz / 1 MHz stability/accuracy
  - With other laser diodes / references: Potential <100 Hz / 1 kHz stability/accuracy

Technology

- Low SWaP, cost: (1 liter, 0.5 kg, 10 W / SmallSat)
- All-digital control (FPGA), all "COTS" fibre-optics

TECHNOLOGY OVERVIEW

- Put everything into software
  - ADCs/DACs & DSP from SDR research
  - High resolution / high speed
  - Optimised analogue front ends
  - FPGA control
- Put everything into fibre
  - Any diode laser
  - UV/VIS/NIR Fibre components
  - Telecorida standards / "Plug & Play"
  - Compatible: Fraunhofer / Ferdinand Braun / JLIQS



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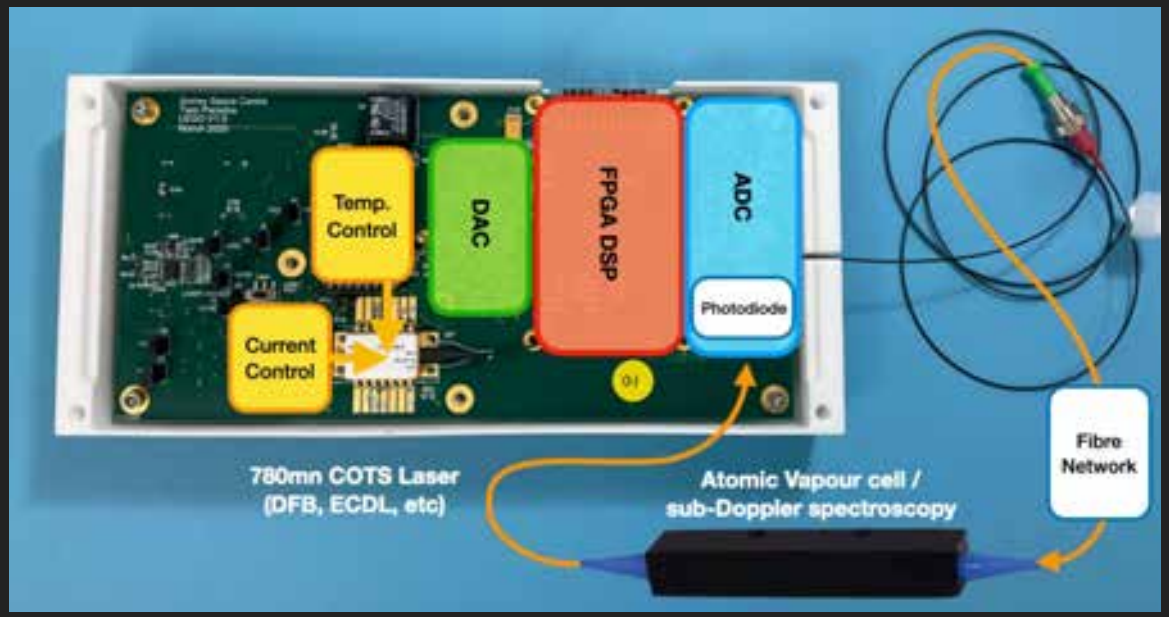
DIGITAL DESIGN

- Single PCB module
  - Power, DSP, laser control, etc.
  - Overcurrent/voltage protections (SEU)
  - Telemetry & monitoring circuits
  - USB / UART / CAN-FD
- All Digital control
  - Optimised VHDL → ~20% of Spartan 6
  - FIR, IIR filters
  - MHz bandwidth FM spectroscopy
  - MHz bandwidth PID control



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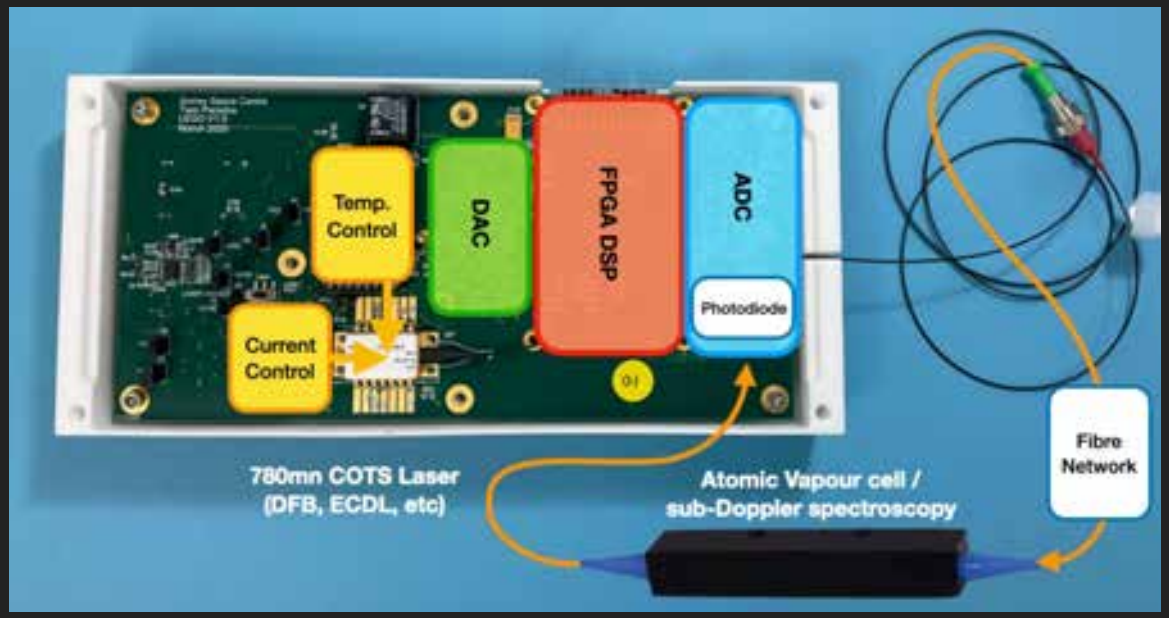
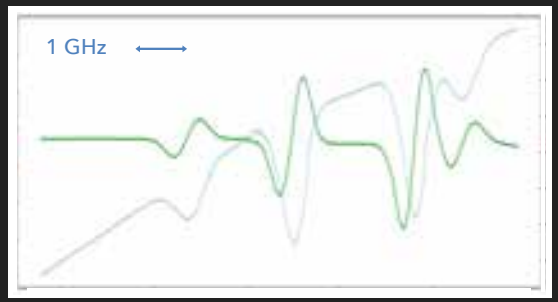
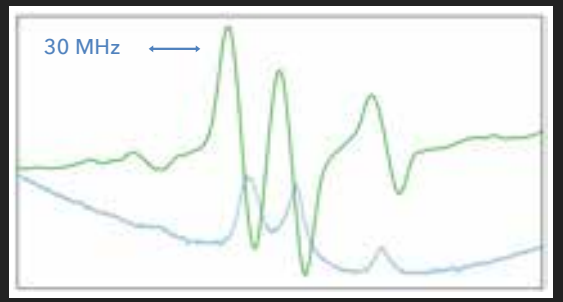
OPTICAL & ATOMIC DESIGN

- Rubidium Sat. Spectroscopy
  - FM / PDH spectroscopy
  - Polarisation control
  - All fibre sub-Doppler optics
  - Mount to electronics enclosure lid
- Opto-electronics
  - Flexible laser driver
  - **For this project:** 10mW output DFB
  - **Future?:** 500mW VHG/Hybrid-ECDL
  - 100MHz high-gain photodiodes







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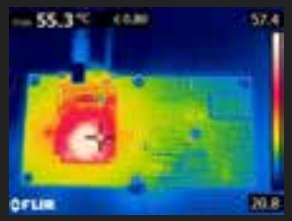
Current Status

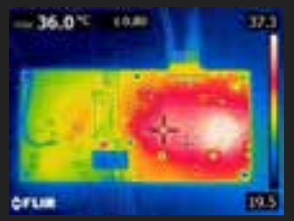
Science

- 10 kHz Db stability (in-loop estimate)

Technology

- 1 litre (20 x 10 x 5 cm), 300 g, 7 W
- Immediate Goals
  - 'Out-of-loop' confirmation
  - sub-Doppler stability measurements
  - Environmental testing



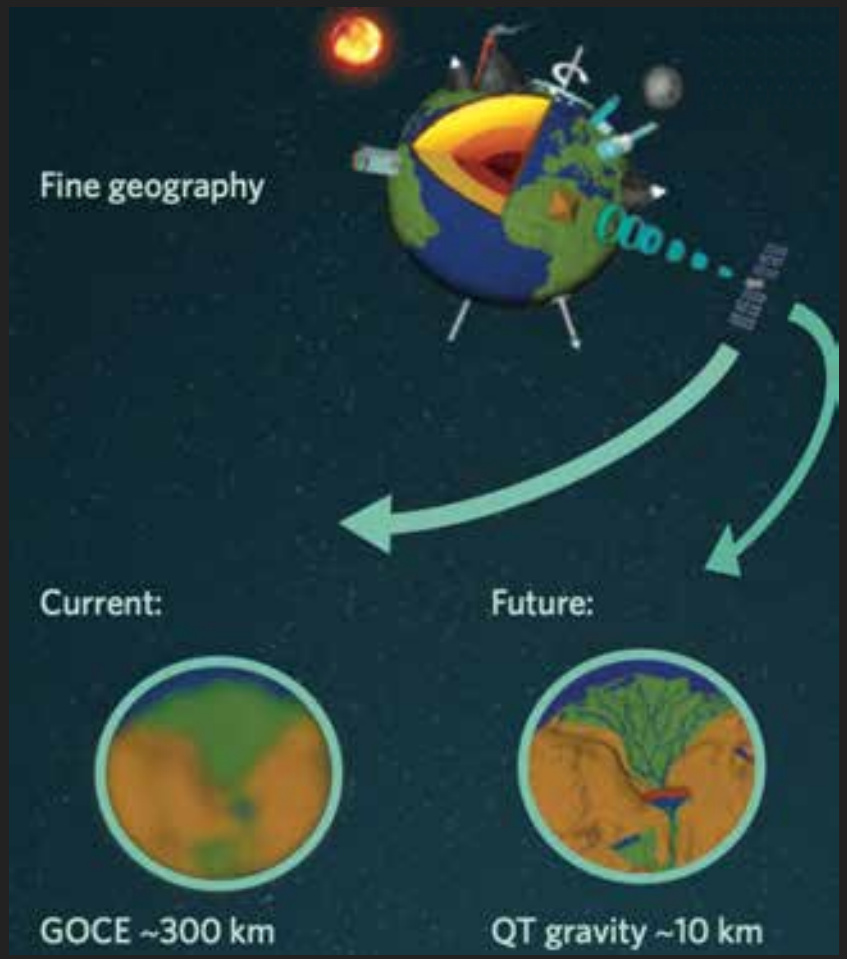


WHERE NEXT?

- Frequency Agility
  - GHz tuning
  - Arbitrary spectrum generation
- Optimizations
  - Improve bandwidths, resolution, etc.
  - More SWaP reductions
- Applications!

  Atom Interferometer & Atomic Clocks (cooling & clock laser)

  → Seeking collaborations!



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