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The Rapidly Expanding Need for Quantum Atomic Clocks

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NDIA Emerging Technologies for Defense Conference,
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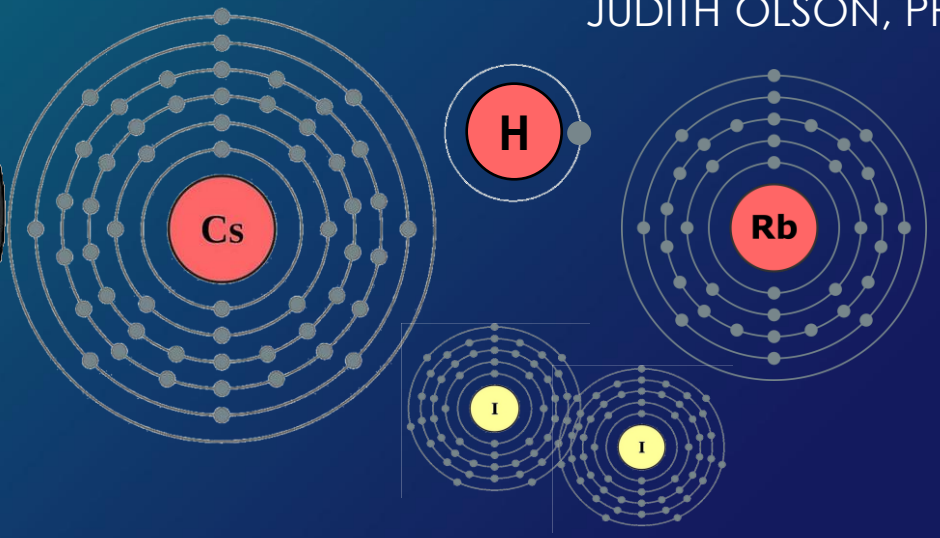


Atomic clocks are core to defense

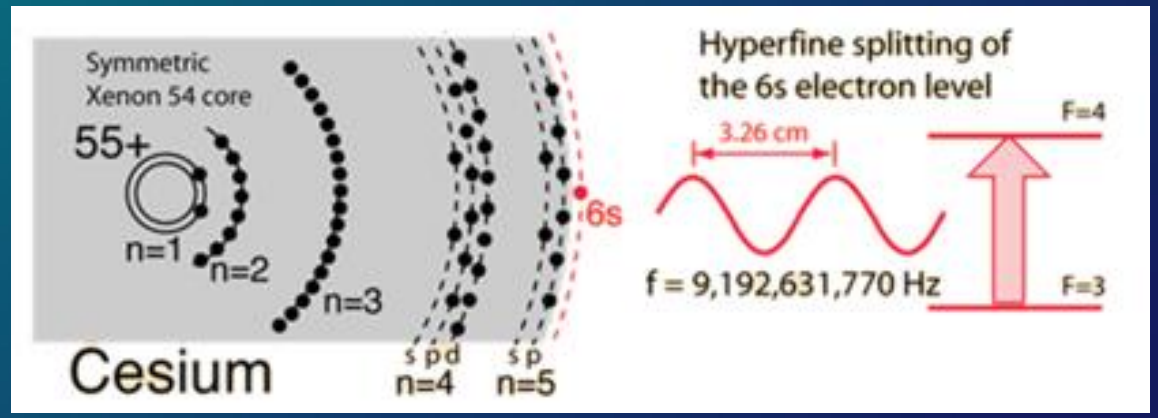
- Navigation and timing (GPS)
- PNT resiliency and GPS-free UAVs
- Data and communications
- Phase-based radar
- Critical infrastructure management
- "Quantum suite of sensors" modality

Images of atoms from https://www.chemistrylearner.com/

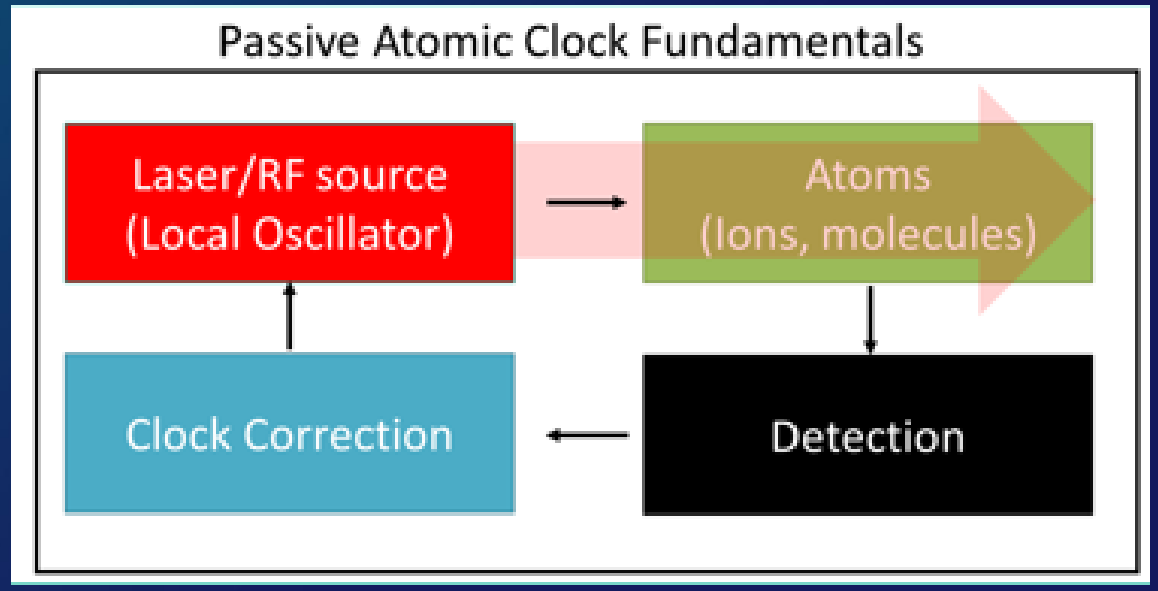
Atomic clocks have rapidly improved

- Traditional timing solutions are combination of microwave (RF) atomic clocks and crystal oscillators as basis

- A new type of atomic clock, the **optical atomic clock**, offers superior performance with a laser as its timing basis

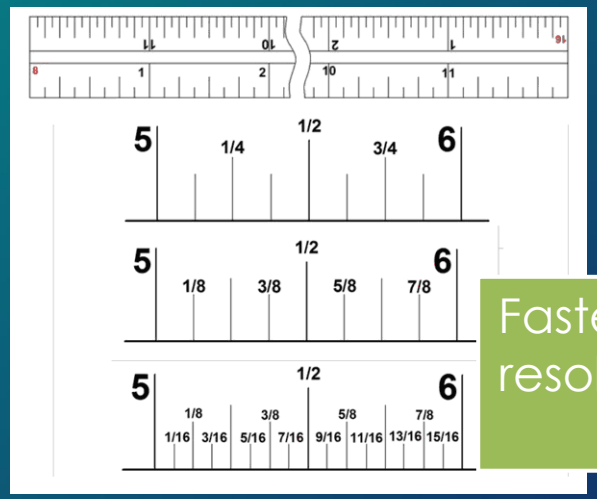


By counting the 'ticks' of the clock, we can tell time (and extrapolate position)

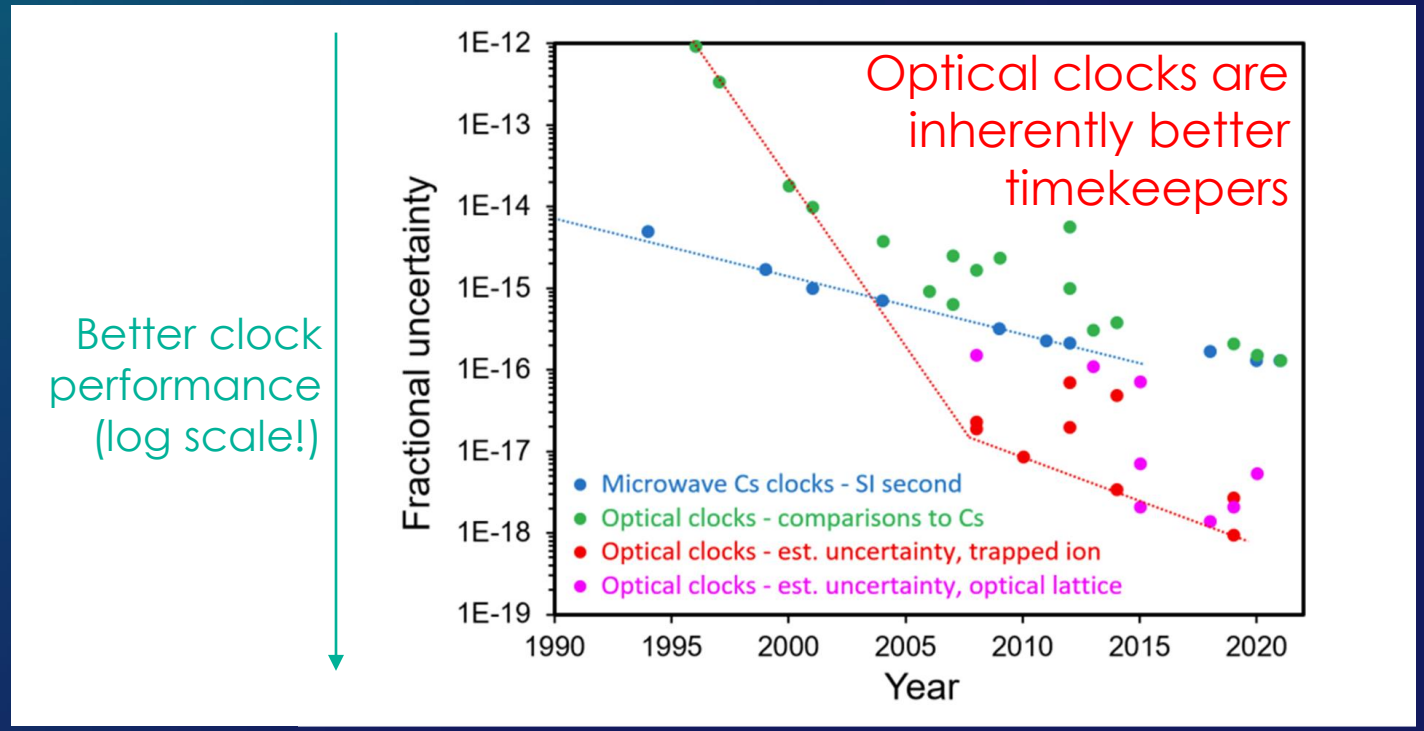


Optical clocks: the future of timekeeping

- Performance ∝ **fractional frequency instability**
- Optical clocks (100's THz) tick ~10,000 x faster than microwave clocks (10's GHz)
- **10,000x improvement in timing *and* environmental susceptibility** possible



Faster 'ticking' clocks allow better timing resolution and measurement, like having more ticks on a ruler

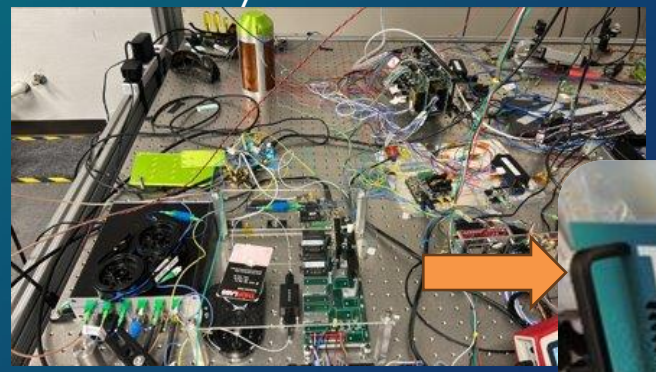


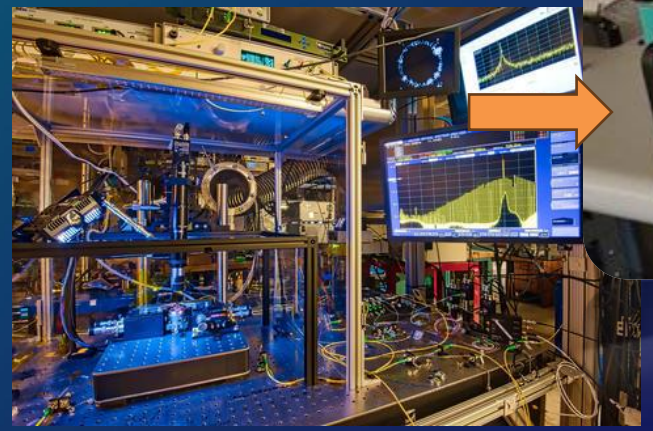
(Plot from NASA Cold Atoms in Space Workshop 2022 publication)

Optical clocks are ready and needed

- Optical versus microwave clock performance and **fieldability** greatly improved
- Biggest technology barriers to commercial deployment are lowering (TRL and MRL)
- Emerging mission needs exceed current capabilities

Laboratory bench clocks





NIST comb lab

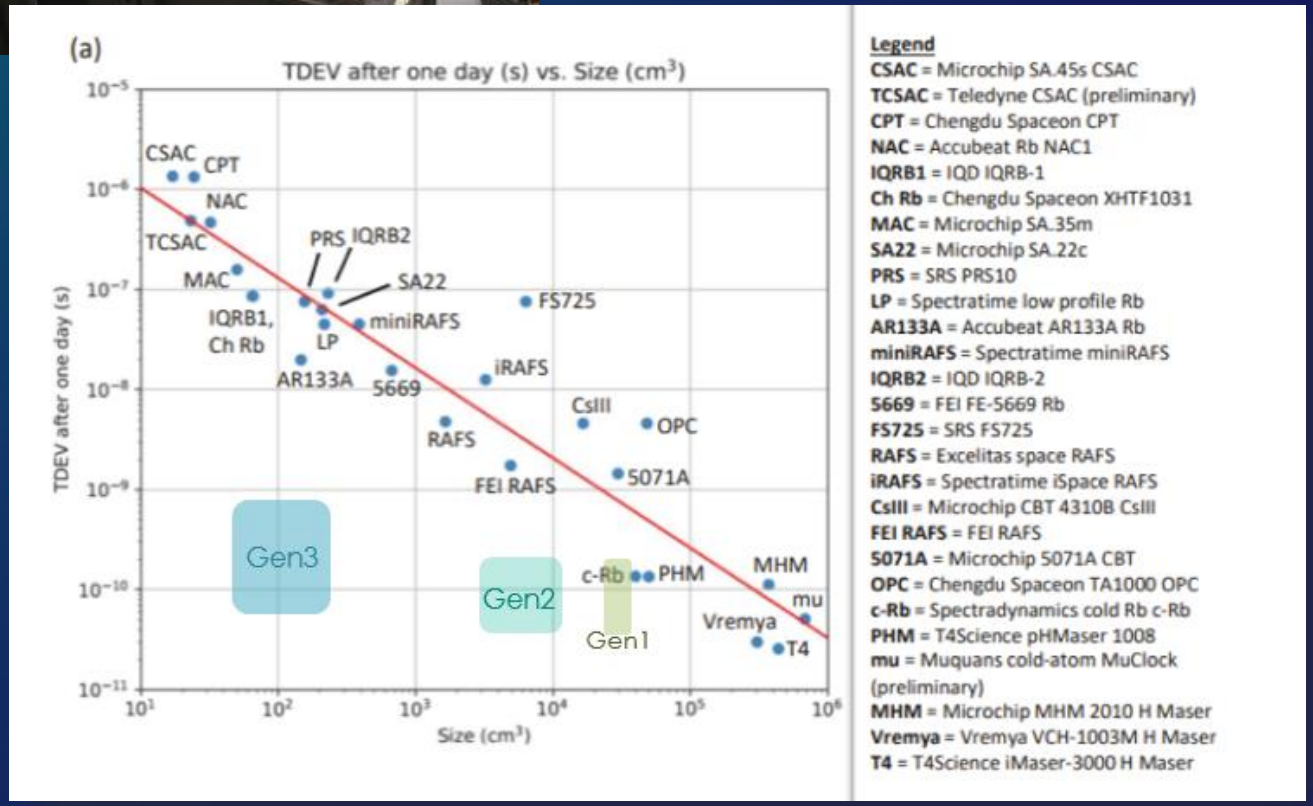
Commercial optical clocks today

- Optical clocks coming to market now, pre-production units available
- Maser-like performance with added benefits of:
  - More fieldable, ruggedized
  - Lower cost
  - Shorter lead times
  - Much smaller size
  - Better holdover/drift performance

Pre-Production

Tiqker Prime (Gen1)

Tiqker HD (Gen2)



Areas of interest for near-term clocks

Pre-Production

Early adopters and those wanting to ensure future compatibility with optical clocks
- Pilot Program underway

Tiqker Prime (Gen1)

"Office-use" version for
- Data networks
  - Meshed, distributed
- Financial institutions
- National timescales
- Science and research facilities
- Tests and demos of new capabilities

Tiqker HD (Gen2)

Ruggedized version for deployed and mounted scenarios
- Intelligent surveillance and reconaissance
- Autonomy
- Radar

Contact for Pilot Program information:
Too Vira, Director of Product Engagement
too.vira@infleqtion.com

Defense partnerships

- Goals:
  - Provide demo units to integrate with existing PNT hardware
  - Improve MRL – Accelerate vapor cell manufacturing and photonic integration capabilities to enable reduced SWaP-C and production at scale
  - Improve TRL – Develop ruggedize clocks and certify to mil-spec for ground, sea, and air missions; pursue space qualification

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We'd love to hear from you at Judith.Olson@Infleqtion.com