Laser Cooled Atomic Clocks in Space

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Clock Operation: Example

Collect: \( N_0 = 8 \times 10^7 \) cold atoms/ball
Launch: \( N_{m=0} = 9 \times 10^6 \) in \( m=0 \) with 2 balls/s
Detect: \( N_D = 1.5 \times 10^4 \)
Ramsey Time: \( T_R = 5 \) s
Cycle Time: \( T_c = 15 \) s

Source “brightness” achieved so far:
1) \( N_0 \sim 2 \times 10^8 \) (in 1 sec.) in vapor cell molasses (Ch. Salomon, Paris)
2) \( N_0 \sim 5 \times 10^7 \) (in 1 sec.) in small beam filled molasses (NIST Fountain)
GLACE: Glovebox Laser-cooled Atomic Clock Experiment

**Principle Investigator:** K. Gibble (Yale)

**Goals:**
- First utilization of tunable, frequency-stabilized lasers (300 kHz @ 852 nm) in space.
- Demonstrate laser cooling and trapping in microgravity.
- Demonstrate longest ‘perturbation-free’ interaction time for a precision measurement on neutral atoms.
- Resolve Ramsey fringes 2–10 times narrower than achievable on Earth.

**Approach:**
- COTS components (HP 5071 cavity, commercial lasers and vacuum components).
- Utilize prototype hardware from LCAP flight definition experiments.

**Launch date:** Oct. 2002 (UF-3)
Space Qualification of Components

Shuttle requirements:
• Vibration Testing:

<table>
<thead>
<tr>
<th>Freq. Range</th>
<th>Design/Protoflight (PF)</th>
<th>Flight Acceptance (FA)</th>
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<tbody>
<tr>
<td>20 to 150 Hz</td>
<td>+6dB/Octave</td>
<td>+6dB/Octave</td>
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<tr>
<td>150 to 1000 Hz</td>
<td>0.06 g2/Hz</td>
<td>0.03 g2/Hz</td>
</tr>
<tr>
<td>1000 to 2000 Hz</td>
<td>-6dB/Octave</td>
<td>-6dB/Octave</td>
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Duration: Design: 2 minutes; PF or FA test: 1 minute

• Temperature:
Must survive over a -5 to 50 C range

New Focus Vortex laser on vibration test bed at JPL
ISS Science Platforms:

Express Pallet

• For External Payloads

Microgravity Science Glovebox (MSG)

• 260 liter working volume
Microgravity Science Glovebox

MSG specifications

- **Working volume:**
  260 liters (92 cm×65 cm×50 cm)

- **Vibrational isolation:**
  Frequency Range  RMS Acceleration
  0.01–0.1 Hz  < 0.21920 μg
  0.1–100 Hz  < f×0.21920 μg/Hz
  100–300 Hz  < 219.20 μg

- **Electrical power**
  1000 W (8.3 A @ 120 V, 7 A @ 28 V, 2 A @ ±12 V, 4 A @ 5 V)

- **Heat dissipation**
  1000 W (800 W via coldplate, 200 W via air flow)

- **Data I/O**
  RS-422, MIL STD 1553B, digital I/Os, analog outputs, ethernet.