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Pasadena, CA 91109
California Institute of Technology
Jet Propulsion Laboratory
Technology Group
Time and Frequency Sciences and

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Dave Siedel, R.J. Thompson, W.M. Klibstein,

Laser Cooling and Atomic Physics (LCAP) Program
Clock Technology Development in the
Credits

Valé: Glace, Race, LACATS

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GPS Career Phase:

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Rob Thompson (Instrument Manager)
Dave Siedel (Systems Engineer)

JPL: LAP Program
I. With some science return.

- Capability for relativistic experiments, less of spatial ionopy. Test time transfer and clock technology.
- Flight of laser-cooled microgravity atomic clock alone with high stability ion clock/master and GPS.

Space Shuttle

For at least 30 days, use of clock for relativistic experiments and cold collision studies.

- Laser-cooled rubidium clock for ultra-precise atomic clock, to operate continuously.
- RACE (Rubidium Atomic Clock Experiment): Yale.

PARCS (Primary Atomic Reference Clock in Space): NIST/CU

International Space Station

II. Overview of LCAP Flight Projects
SUMO (requires cavity oscillator such as Kennedy-Thorne)
Measurement System
Vacuum Requirements
Light Blocking/Shutters
Thermal Control
More Magnetic Field Control
Cavity
Synthesizer
Local Oscillator
Microwave Electronics

Atom Source
Magnetic Field Control
Electronics
Computer Control
Vacuum Chamber
Fluorescence Detection
Fibers
Optical Frequency Control
Lasers

Laser Cooling Source

Space Clock Challenges

Clock Parts
ISS Science Platforms
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Constraint</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>45 cm</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>46 cm</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>87 cm</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>162 liters</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>&gt; 500 W</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>&gt; 130 kg</td>
<td></td>
</tr>
</tbody>
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**NOTE:** Space indicated provides a unit handle only.
- 100x Earth dose
- Radiation:
  - Humidity: 20 to 70%
  - Pressure: 73 to 204 torr (73 to 204 torr for Max Depressurization Rate)
  - Temperature: -5 to 50 °C

Instrument should operate after exposure to:

**Environment:**

**Vibration Testing:**

**Shuttle Requirements:**

Space Qualification of Components
Laser Configuration

38 cm
46 cm

To lock
second layer: repump
First layer: master laser
and frequency control
and laser lock
Frequency Transmitter
Clock Rate Comparisons: GPS Carrier Phase
Give Position Information to 100 m
Existing GPS antenna will see between 3-6 satellites

Visibility of satellites (desire ~ 12 in view)
Multipath worst case (need ~ -70 dBm)
No high quality RF/optical link between interior/exterior
Need external antenna

Issues:

1 m/m/s velocity information
> 10 cm position information
100 ps resolution

GPS carrier phase technique expected to give:

GPS Carrier Phase Frequency Transfer
Another "Normal" View

ISS Model Views