The Gem Infrasound Logger: A Lightweight, Low-Power, Low-Cost, Open-Source Infrasound Logger

Jacob F. Anderson
Boise State University

Jeffrey B. Johnson
Boise State University
The Gem Infrasound Logger: a Lightweight, Low-Power, Low-Cost, Open-Source Infrasound Logger

Jacob F. Anderson¹, Jeffrey B. Johnson¹, Daniel C. Bowman², Timothy J. Ronan²

¹Department of Geosciences, Boise State University. ²Sandia National Laboratories. ³Geophysical Institute, University of Alaska Fairbanks

Limitations of Existing Infrasound Logging Systems

- Expensive data loggers with limited selection
- Recording in risky sites and platforms discouraged by high cost
- Expensive, awkward cabling needed for sensor connections
- Long installation time due to cable management, concealing
- Heavy and bulky: difficult to transport, aerial use limited to very large platforms
- Complex, error-prone installation procedure

Installation steps

1. Array size
2. Recording size
3. Installation steps
4. Time to install and
5. Cost
6. Weight

Solution: the Gem Infrasound Logger

- Inexpensive, can be built in lab with student labor and basic tools
- Light weight and small size
- Fast, simple, cable-free setup procedure
- Lower power consumption, longer battery life than other options
- Easy to customize for specialized applications: user can modify code, enclosure, sensor, and signal conditioning parameters
- Gem described in detail in [1]; code and designs available at [2]

Infrasound logging in particular requires precise sample timing (±2.5 ms), moderately high resolution (±2.5-bit) and sample rate (±500 Hz), anti-aliasing filtering, and moderate amplification (gain ≥ 20). The following additional components are required for infrasound:

- Analog signal conditioning (low-pass filter, instrumentation amplifier)
- GPS (for precise timekeeping)
- Infrasound sensor [3]

Gem vs. Best Commercial Logger (DATACUBE-3)

<table>
<thead>
<tr>
<th>Gem vs. DATACUBE-3</th>
<th>DATACUBE-3 logger with 3 infraBSU sensors</th>
<th>Gem Infrasound Loggers with 3 sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Normal 2975 g; Minimum 1100 g for 1 sensor</td>
<td>Normal 1100 g; Minimum 78 g for 1 sensor</td>
</tr>
<tr>
<td>Cost</td>
<td>~$3000</td>
<td>~$1000</td>
</tr>
<tr>
<td>Time to install and take down</td>
<td>9 minutes (much longer if cables need to be concealed)</td>
<td>3 minutes, no cables to conceal</td>
</tr>
<tr>
<td>Installation steps</td>
<td>13 without confirmation, 1 with confirmation</td>
<td>6 with confirmation</td>
</tr>
<tr>
<td>Open-source?</td>
<td>Yes, hardwire, firmware, and software all open-source</td>
<td>No</td>
</tr>
<tr>
<td>Array size</td>
<td>Up to 15 m from center, multiples of 3 sensors</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

Designing an Infrasound Logger

Several essential components must be integrated to record any sensor to disk:

- Analog-digital converter
- Microcontroller
- Storage medium (e.g., SD card)
- Power supply
- Weatherproof enclosure

The Gem infrasound logger has resulted in its use in several conventional and unconventional infrasound campaigns (three examples shown here). The Gem has so far been adopted for research at six other institutions worldwide.

Application Examples

Fuego Volcano, Guatemala
- The Gem’s high portability enabled one worker to carry ten units with camping gear (left)
- Theft-prone site required low-cost, easily concealed instruments
- Despite noisy setting, dense sensor network led to accurate eruptive gas estimates (right)

Stratospheric Solar Balloons
- High-altitude balloons at float can detect infrasound from distant explosions (right)
- Floating helium balloons are extremely costly; solar hot air balloons reduce total cost by >100x but only carry light payloads
- The Gem is the only known infrasound logger light enough to fly on solar balloons
- Method is being developed for nuclear test monitoring, and for seismology on planets with extreme environments like Venus

References: