Post-Earthquake Monitoring in Myanmar Using Low-Cost Seismo-Geodetic Systems

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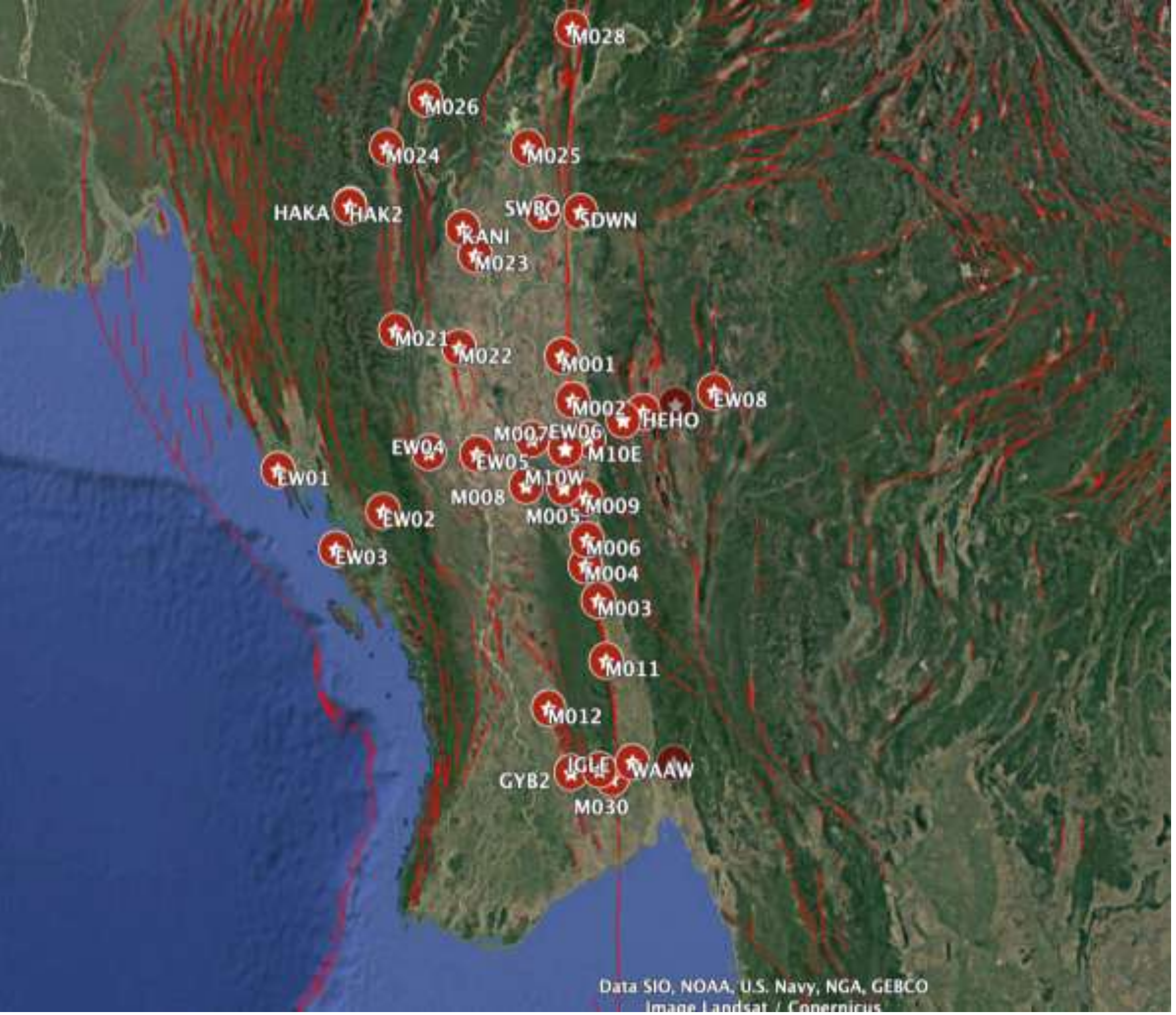
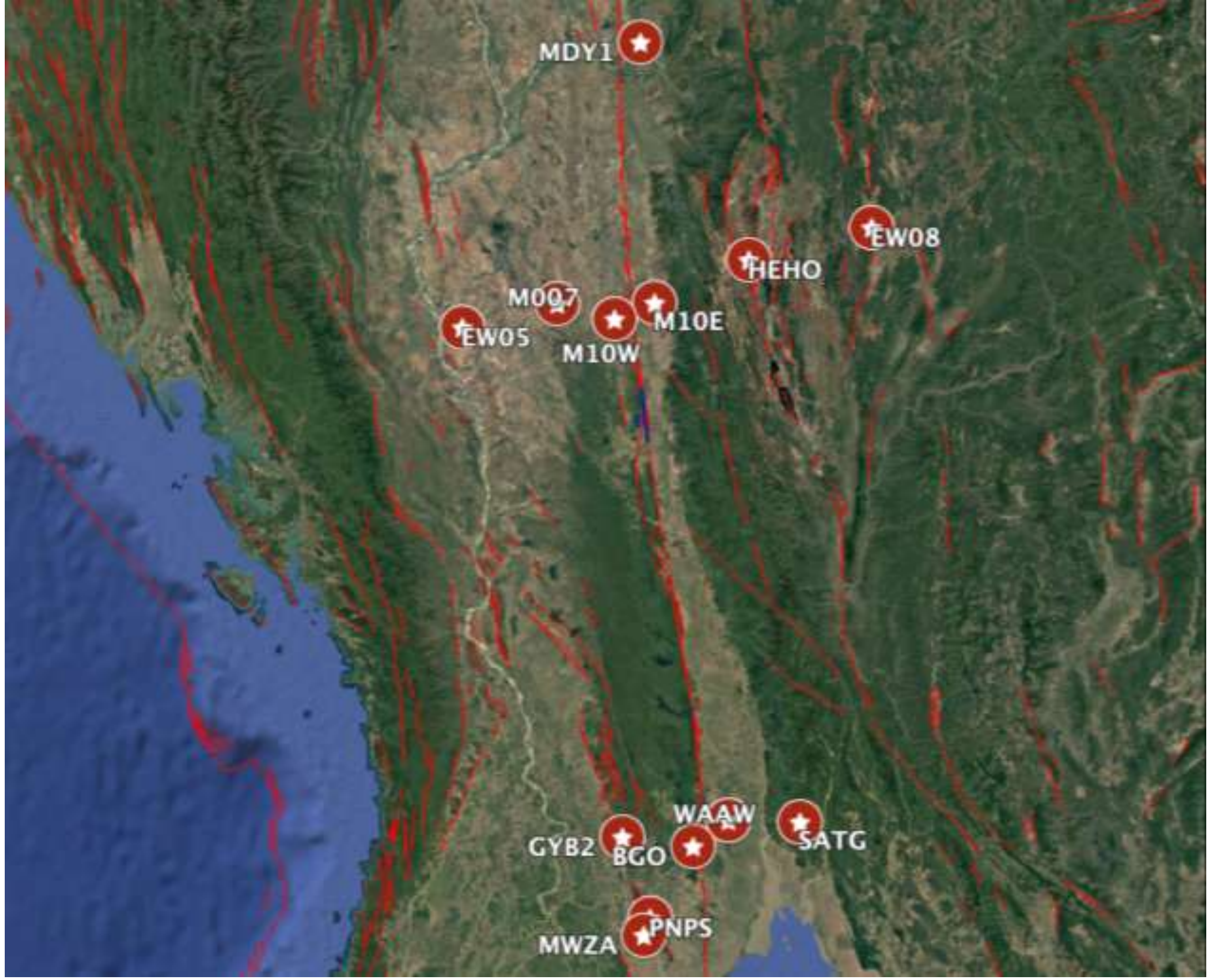
Myanmar Earthquake Committee

2025 Mandalay Earthquake: Motivation

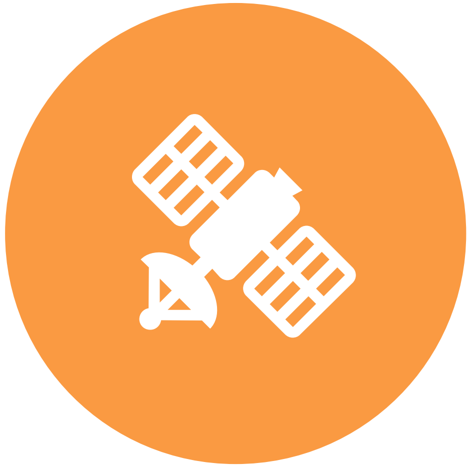
- Significant seismic event affecting Myanmar
- Sparse instrumentation near Sagaing Fault
- Limited real-time monitoring capability
- Need for **rapid, low-cost deployment**





EOS Stations

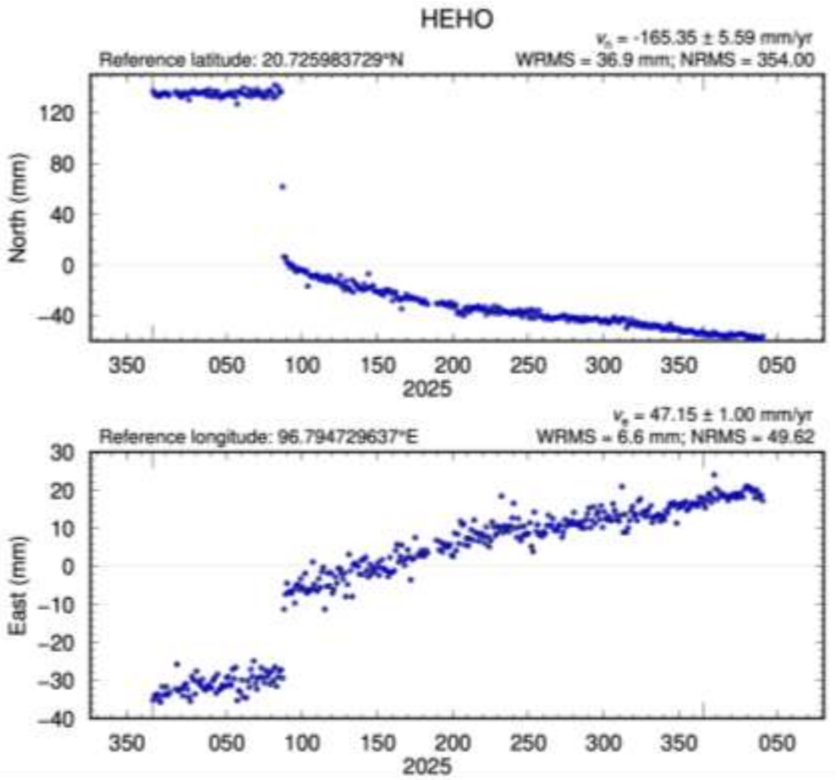
Instrument Type



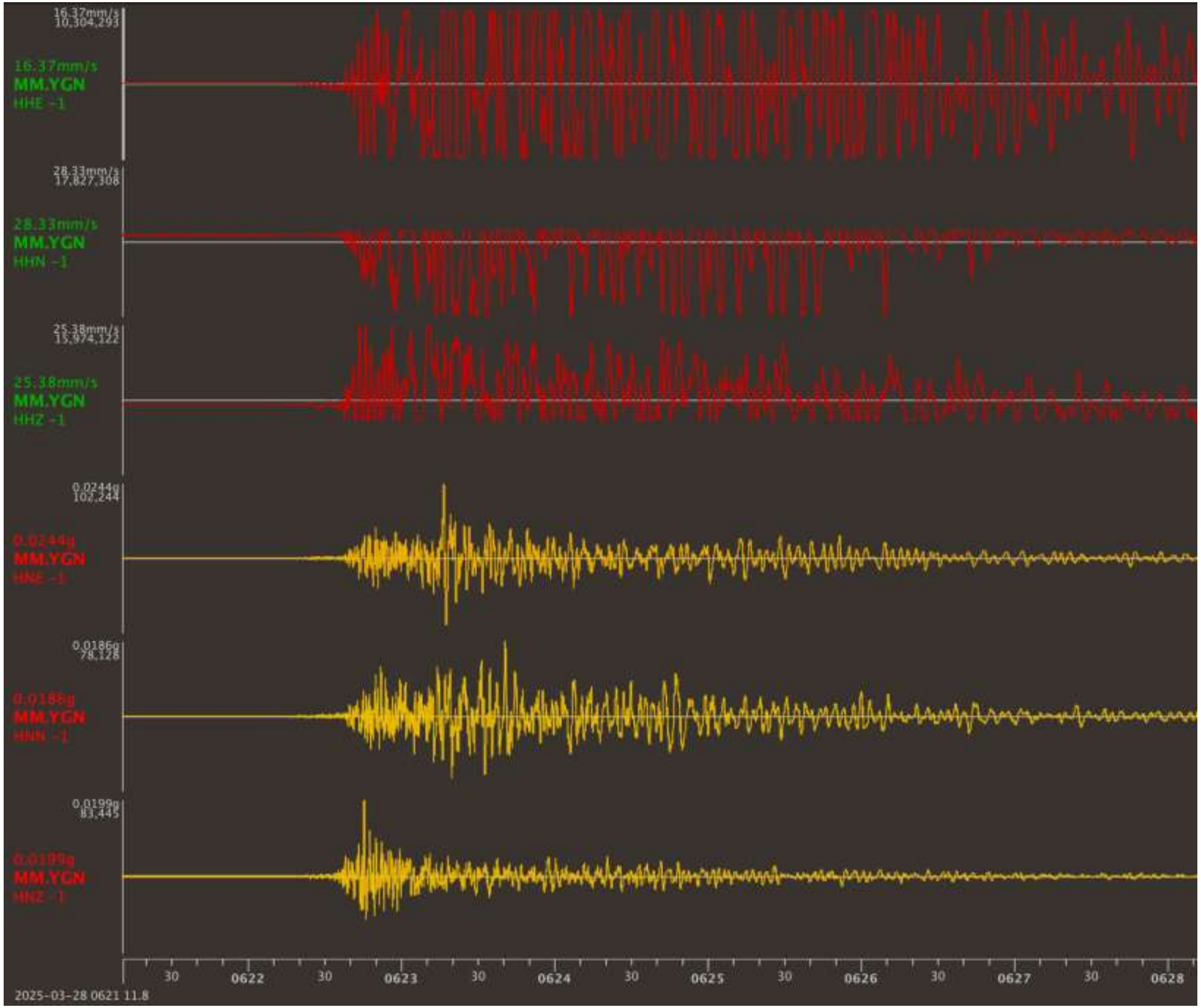
CORS GPS STATION

SEISMIC STATION

- HEHO GPS station



Broadband Seismometer
and
Strong Motion Accelerometer



Broadband Seismometer

Strong Motion Accelerometer

Post-Earthquake Response Strategy

Rapid deployment of monitoring systems

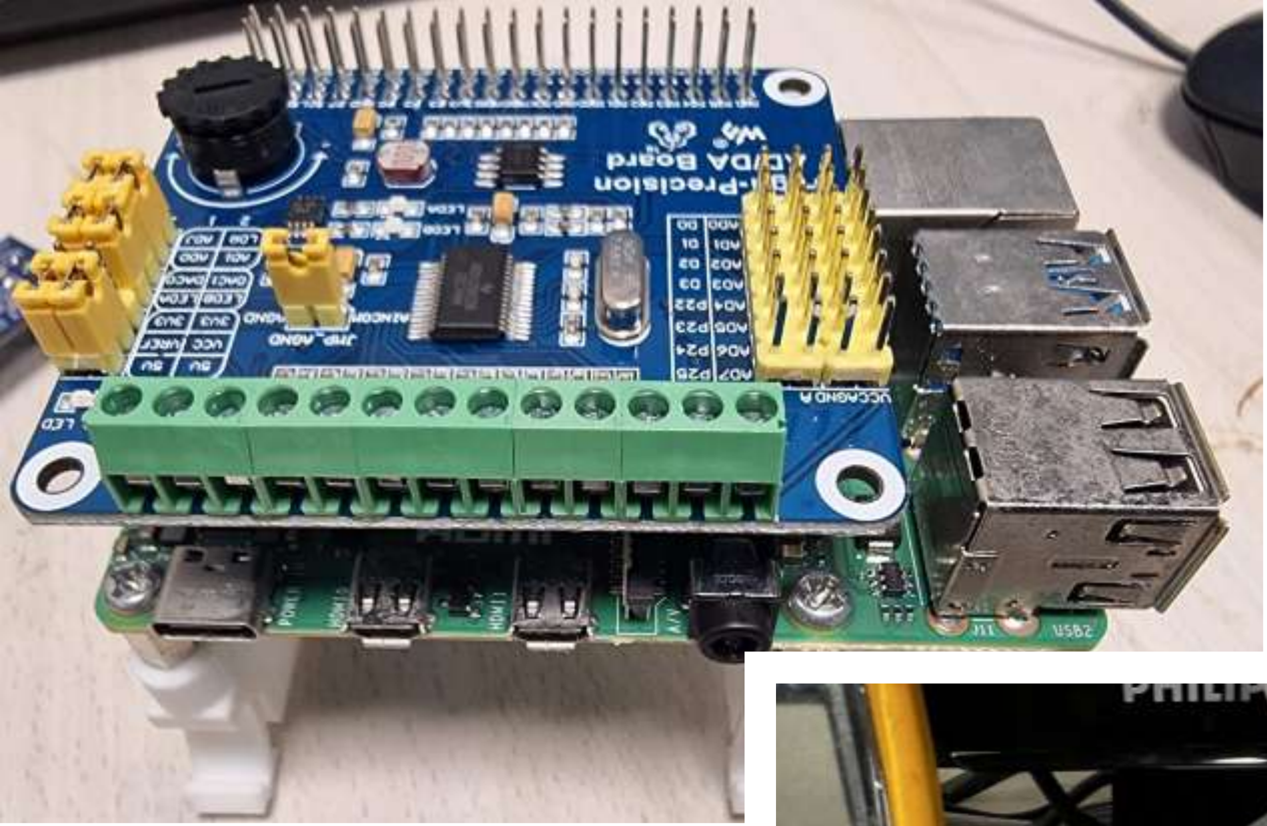
Support existing local networks

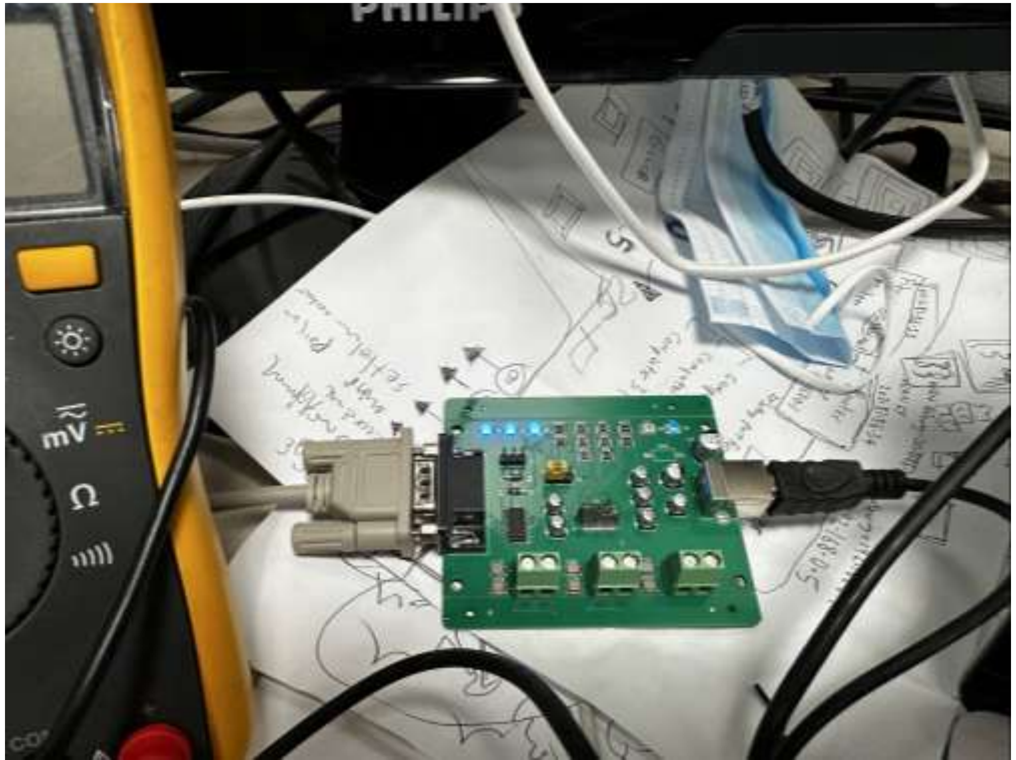
Test **low-cost seismic + GNSS integration**

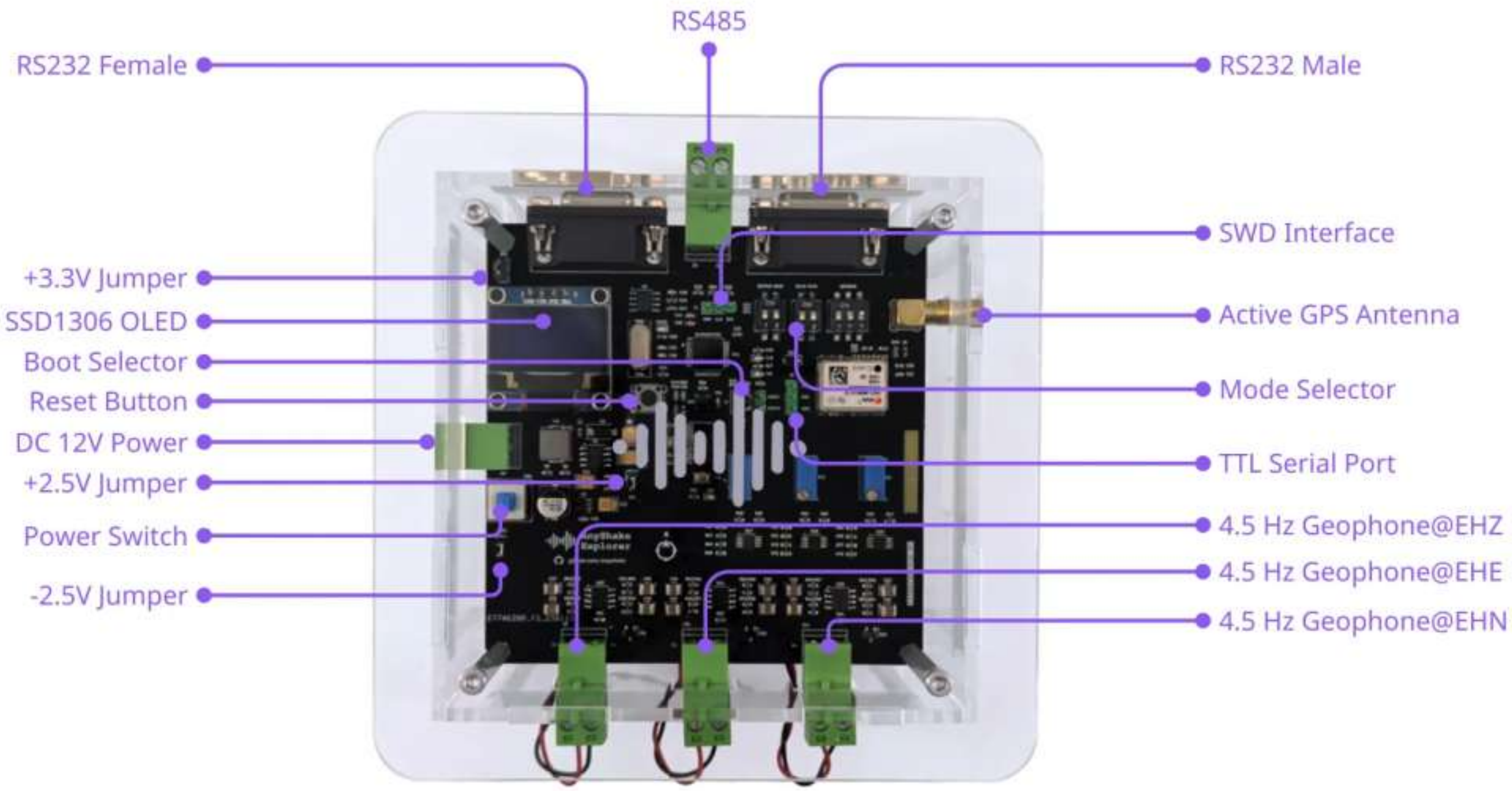
Enable future scalable monitoring in Myanmar

Sensor and System Evaluation

- MEMS sensors tested
  - *(MPU9250, MPU6050, ADXL355)*
- Evaluation of multiple ADC systems
- PSN-ADC24 (higher resolution testing)
- Raspberry Shake (reference system)
- AnyShake (final deployment system)





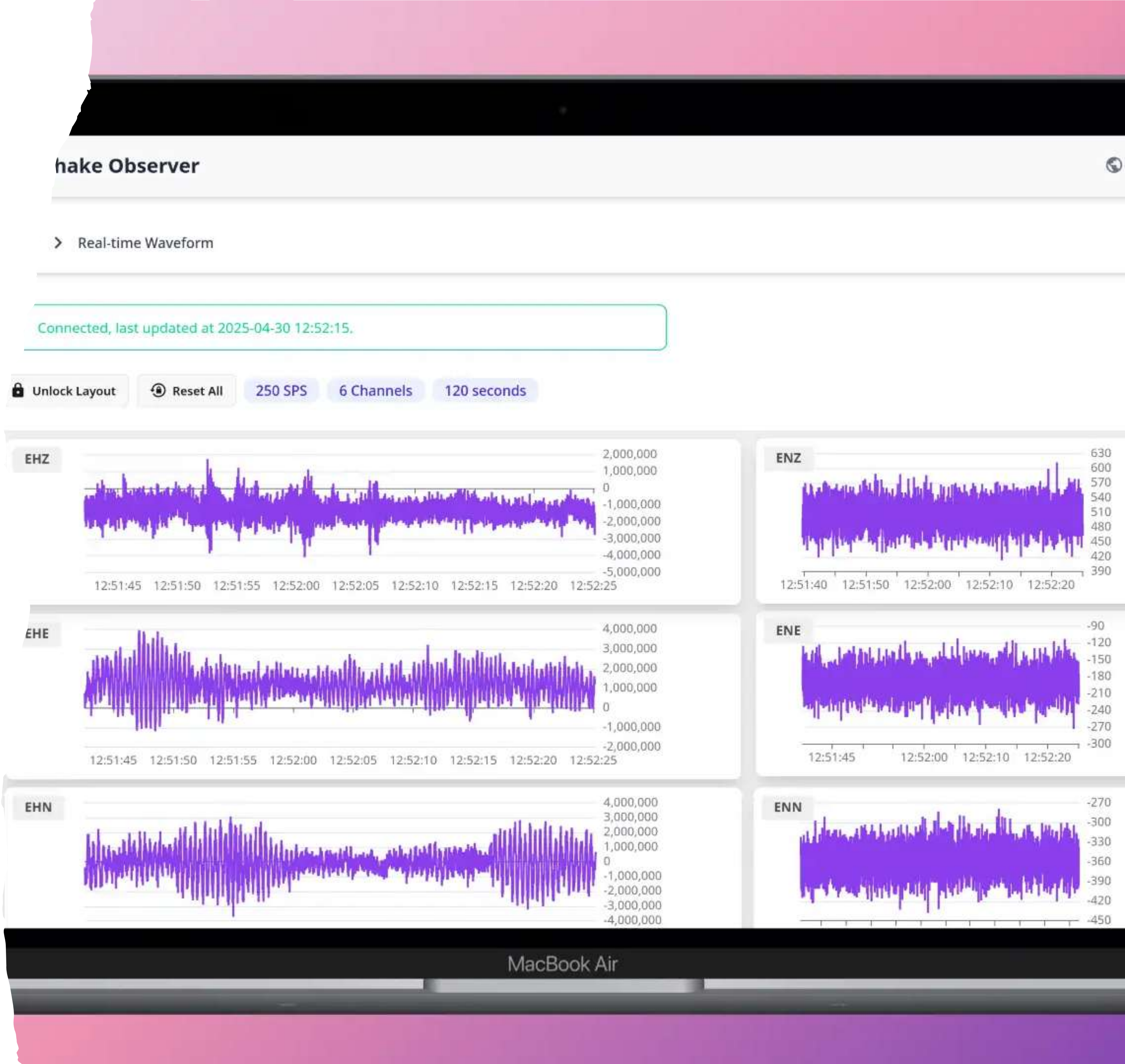

RS485
RS232 Female
RS232 Male
SWD Interface
+3.3V Jumper
SSD1306 OLED
Active GPS Antenna
Boot Selector
Mode Selector
Reset Button
DC 12V Power
TTL Serial Port
+2.5V Jumper
Power Switch
4.5 Hz Geophone@EHZ
4.5 Hz Geophone@EHE
-2.5V Jumper
4.5 Hz Geophone@EHN

Specification

Geophone: 3-axis 4.5 Hz velocity geophone (100 V/m/s sensitivity)
Analog-to-digital converter: High-resolution 32-bit ADC
Accelerometer: 16-bit 3-axis accelerometer (±2 g full scale)
Acquisition: Accelerometer-only mode, geophone-only mode, and simultaneous sampling (6 channels)
Connectivity: 2x RS-232, 1x RS-485, GPS/NTP time sync
Power: 9-12 V DC, ~50 mA
Software: AnyShake Observer (cross-platform, open-source, written in Go)
Data export: MiniSEED, SAC, WAV
Networking: SeedLink protocol support, TCP raw data forwarding
Sampling rates: 50/100/200/250 SPS
Baud rates: 57,600 - 460,800 bps

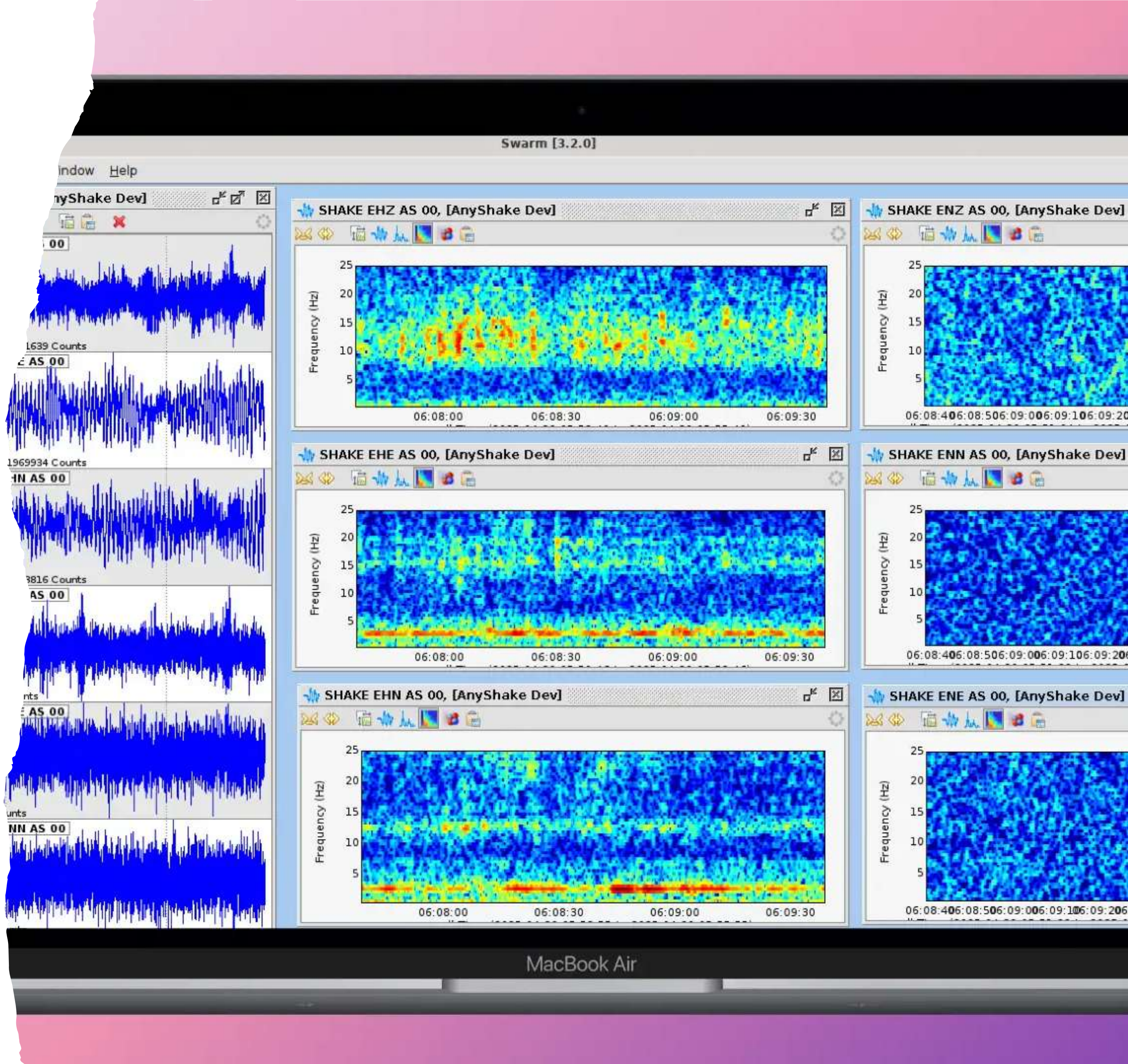
Real-time Waveform

The real-time waveform view displays seismic data and the current sample rate from your AnyShake Explorer device in a web-based interface. It supports zooming, panning, and customizable channel layouts. Layout configurations are persistent and can be locked to prevent accidental changes.



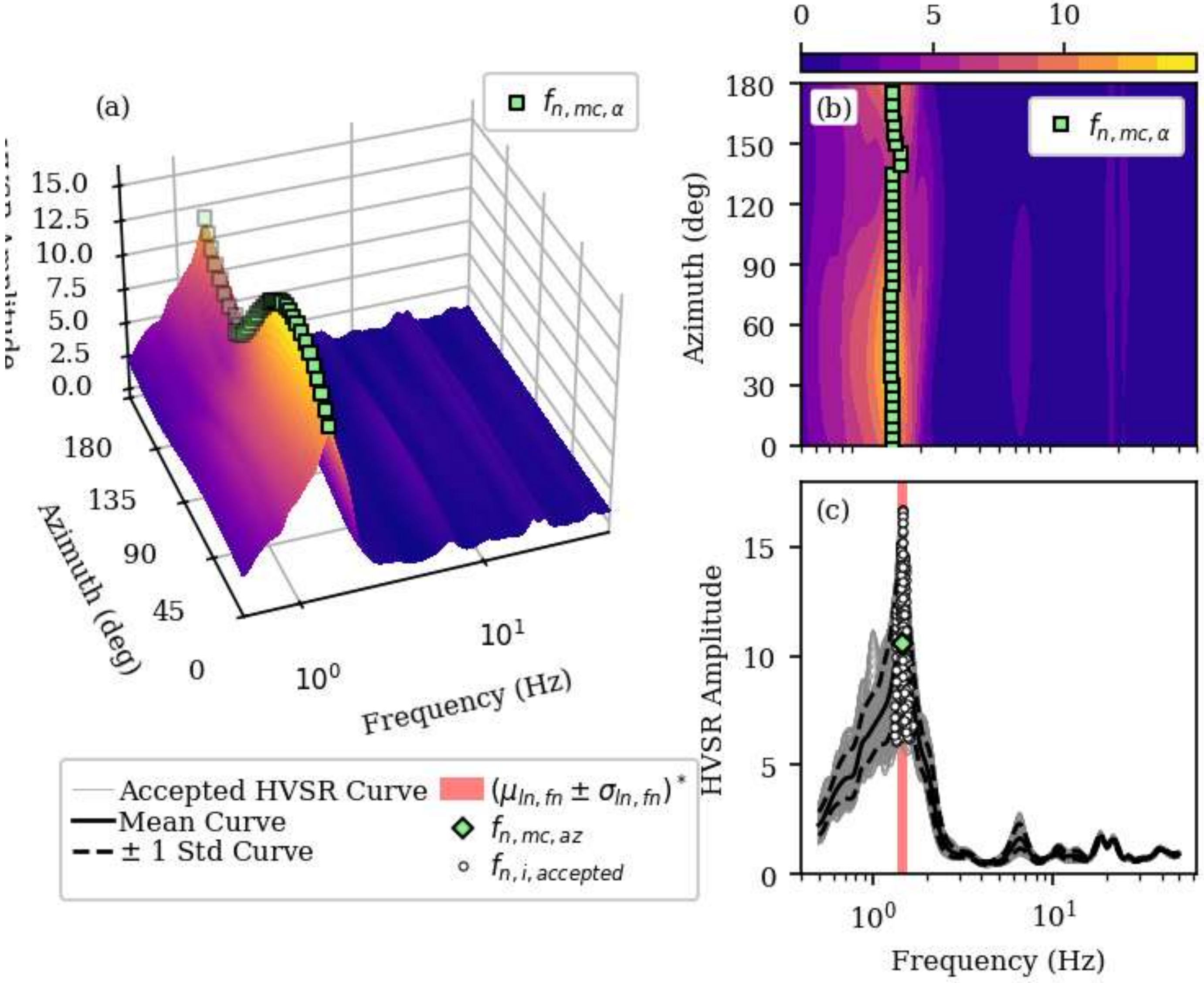
SeedLink Streaming

- The AnyShake team independently developed a SeedLink protocol implementation in pure Go enabling native SeedLink services without relying on RingServer or SeisComP. This allows seamless integration with tools like Swarm and ObsPy.



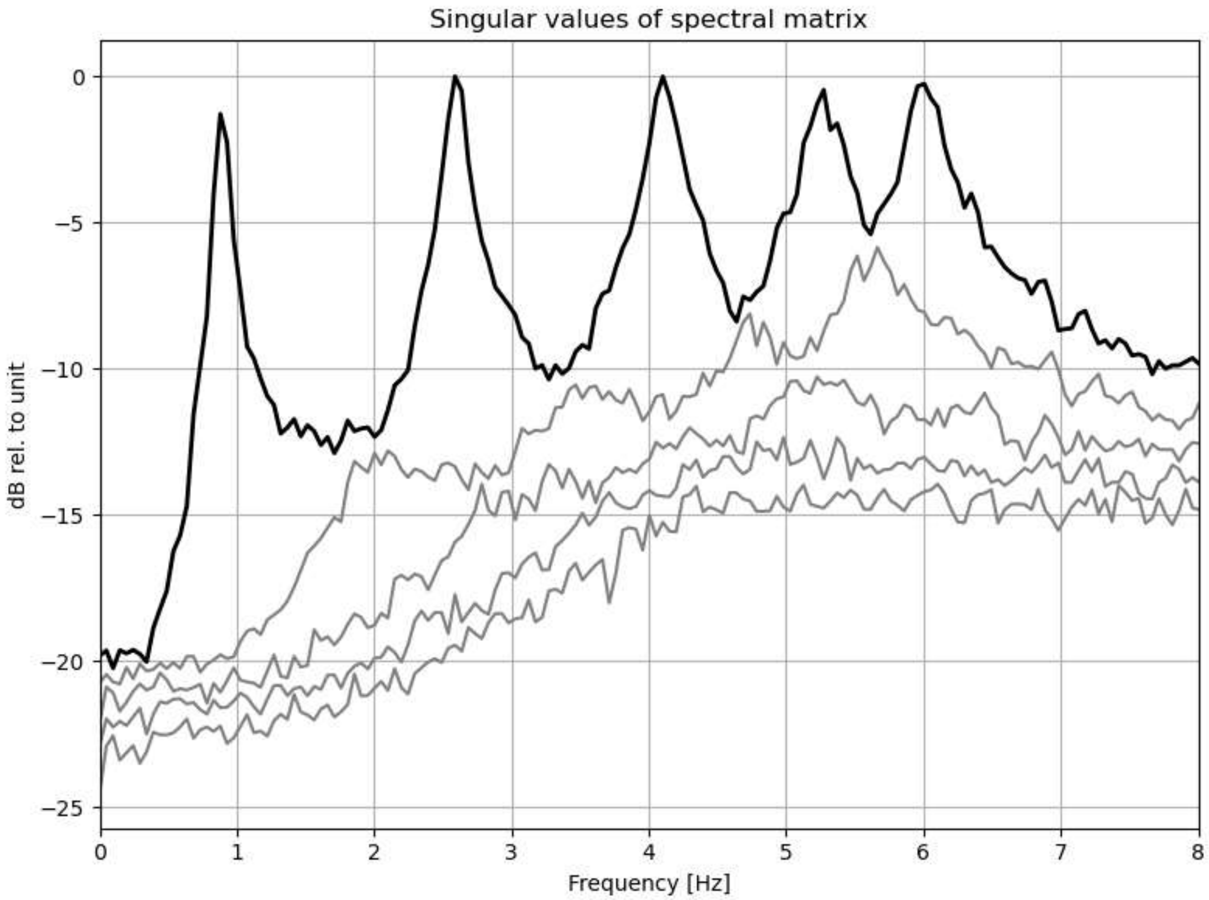
🔷 Typical Applications

- **Seismic microzonation** (earthquake hazard mapping)
- **Building site classification** (UBC97/IBC codes)
- **Bridge, dam, and heritage site safety**
- **Post-earthquake ground condition checks**



Operational Modal Analysis (OMA)

- Extract dynamic properties from ambient vibration
- No need for controlled input (earthquake / excitation not required)
- Estimate:
  - Natural frequency
  - Damping ratio
  - Mode shapes
- Useful for:
  - Structural health monitoring
  - Site response analysis (HVSR-related context)



DIN 4150-3 PPV Limit Table

Structure Type	Frequency Range (Hz)	PPV Limit (mm/s)	Description
Type 1 – Sensitive structures	< 10 Hz	3 mm/s	Buildings of historical value, very sensitive structures
	10–50 Hz	3 to 8 mm/s (linear interpolation)	
	50–100 Hz	8 mm/s	
Type 2 – Residential buildings	< 10 Hz	5 mm/s	Standard homes and apartment buildings
	10–50 Hz	5 to 15 mm/s (linear interpolation)	
	50–100 Hz	15 mm/s	
Type 3 – Industrial/commercial buildings	< 10 Hz	10 mm/s	Less sensitive buildings, e.g., warehouses, factories
	10–50 Hz	10 to 20 mm/s (linear interpolation)	
	50–100 Hz	20 mm/s	

Vibration Monitoring

Vibration Monitoring Report for Tharaba Gate, Bagan

Introduction

Tharaba Gate in Bagan, Myanmar, is significant in both history and culture because it represents Bagan's fortress. Tharaba Gate, which dates back to approximately 1020 CE, is an important landmark that marks the entrance to the ancient city. Given its cultural and structural significance, it is critical to monitor and understand any vibrations that may compromise its integrity and preservation.

Tharaba gate is frequently busy, with visitors coming and going, crossing small cars and motorcycles, Mini Ohway and drinking water delivery trucks. This can result in a high level of ground vibrations, which can be harmful to the structure. Monitoring allows us to understand the nature and extent of vibration, lowering the risk of potentially damaging vibrations negatively affecting Tharaba gate.

Figure 1 - Tharaba gate and slow down bump

Purpose of Vibration Monitoring and PPV

Vibration monitoring is critical for a variety of reasons, particularly in historical structures such as Bagan's Tharaba Gate. Vibration monitoring is used to assess the effect of vibrations on the structural integrity of buildings and monuments. Excessive vibrations over time can cause structural damage, cracks, or even collapse, particularly in older or historically significant structures. Historical sites, such as Tharaba Gate, are often fragile and require special care to be preserved. Monitoring vibrations assists in identifying potential threats to these sites and enabling the implementation of mitigation measures.

Peak Particle Velocity (PPV) is a measurement of particles' maximum velocity during vibration. PPV is an important unit for vibration analysis because it provides critical information about the intensity of vibrations experienced by a structure or its surroundings. PPV is measured in units of velocity, usually meters per second (m/s) or millimeters per second (mm/s), and represents the maximum speed at which particles move as a result of vibration.

This measurement assists in quantifying the severity of vibrations and determining their potential impact on structures or human activities. In the case of Tharaba Gate, measuring PPV enables engineers and conservationists to understand the magnitude of vibrations experienced by the monument and assess any potential risks to its structural integrity or historical significance. By tracking PPV values over time, appropriate measures can be taken to safeguard and preserve this significant cultural heritage site.

Primary Source of Vibration

The primary source of vibration affecting Tharaba Gate is attributed to the road slowdown bumps located in close proximity to the gate. Even if these bumps are not directly adjacent to the gate, the passage of vehicles, especially at high speeds, induces ground vibrations that affect the structure. The vibrations generated by vehicles, particularly SUVs, traversing over these bumps contribute significantly to the measured vibration levels at various points around the gate.

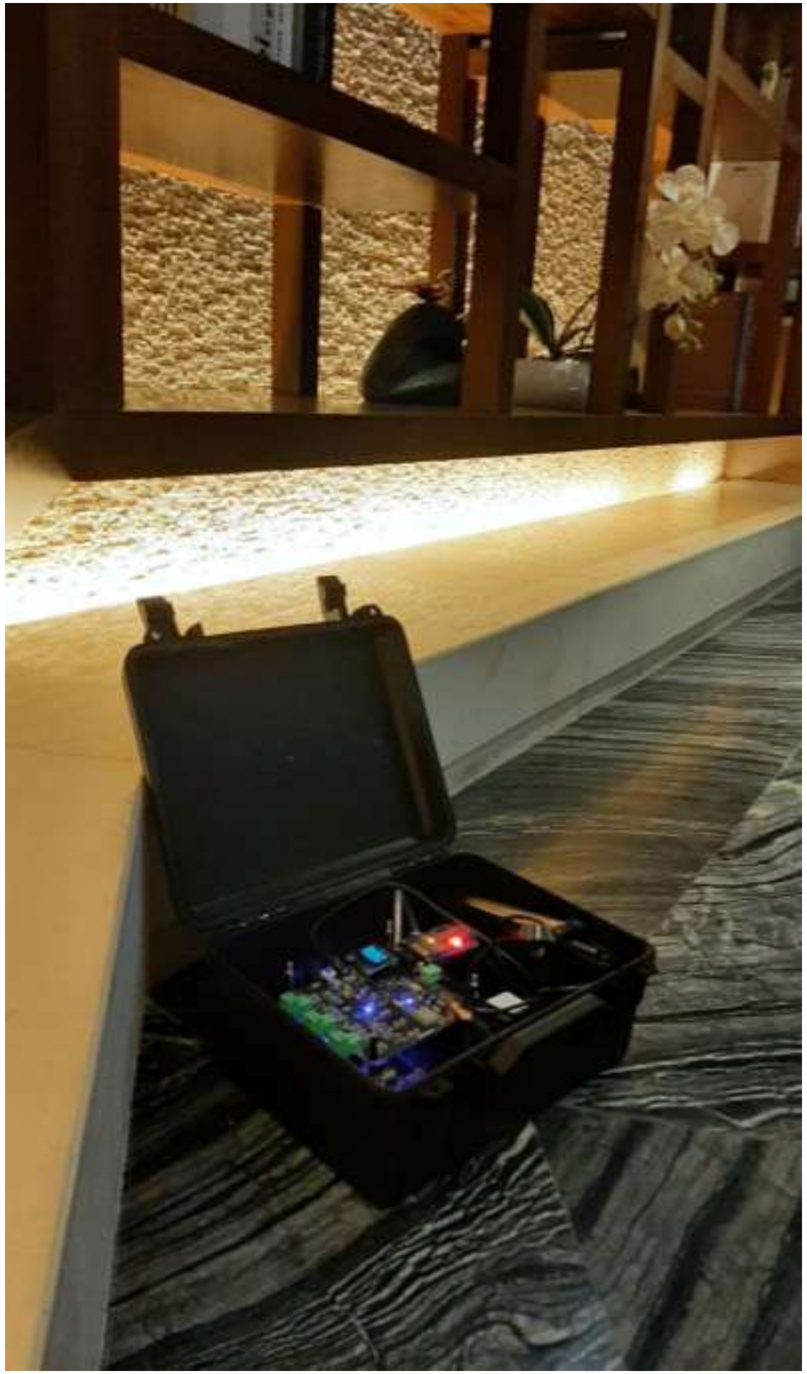
Measurement Locations and Results

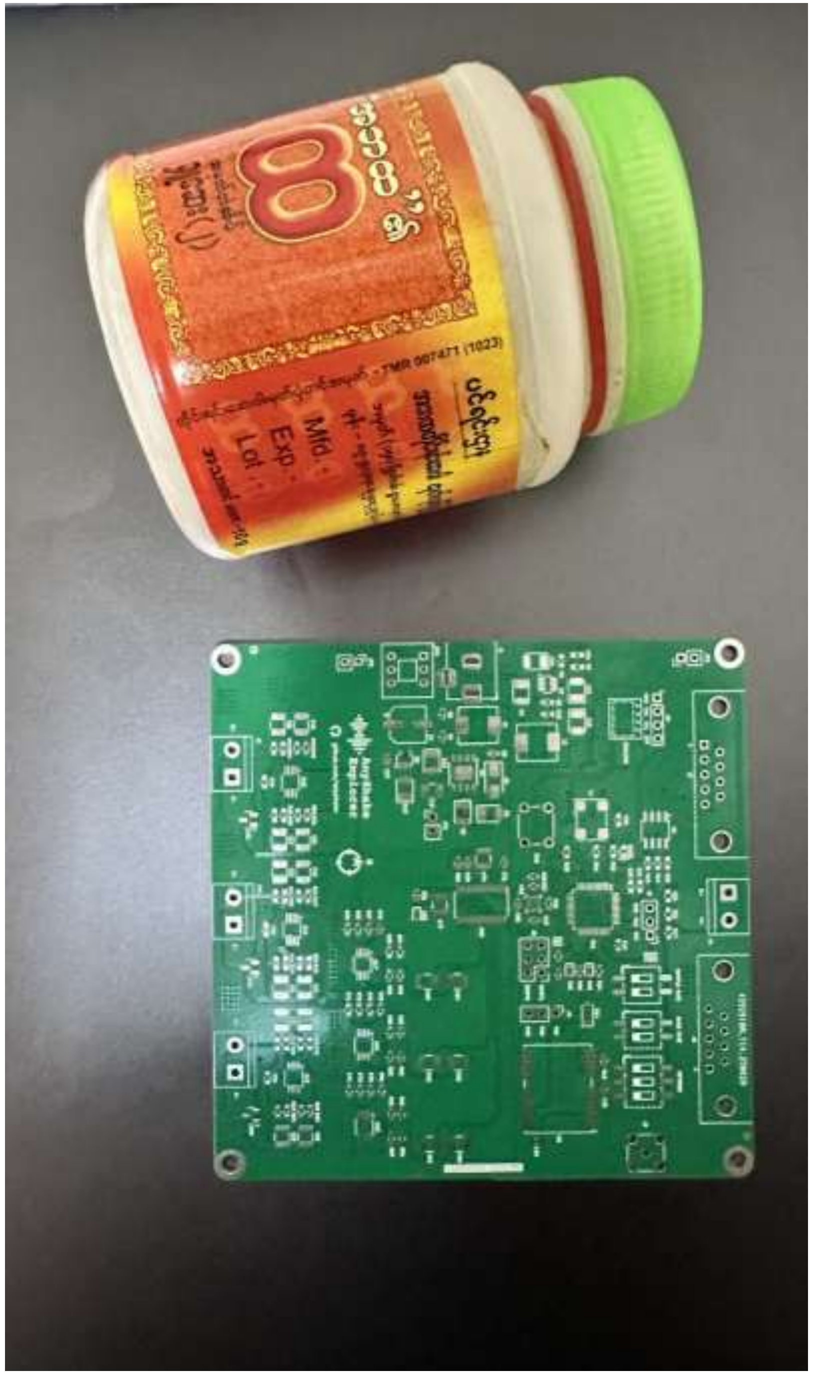
Six measurement points (PT01 to PT06) were identified for vibration monitoring at Tharaba Gate using Raspberry Shake 4D devices. The measurements yielded the following results:

Point	PPV (mm/s)	Frequency (Hz)
PT01	0.038	10.59
PT02	0.25	0.20
PT03	0.115	15.71
PT04	0.054	9.16
PT05	0.060	0.23
PT06	0.041	3.05

Figure 1: Location of the vibration measurement points from Tharaba Gate

Feature	AnyShake Explorer	Raspberry Pi-based Shakes
Open-Source Hardware	✅ Fully Open	❌ Closed Source
Open-Source Software	✅ Fully Open	⚠️ Partial (limited components)
Geophone Channels	3 (X, Y, Z)	1 or 3 depending on model
Accelerometer	✅ 3-axis MEMS	Only 4D model include 3-axis MEMS
ADC Resolution	🔶 32-bit Ultra Precision	🔷 24-bit Standard
Sampling Rate	🔄 50–250 SPS Adjustable	🔒 Fixed at 100 SPS
Built-in GPS	✅ Included (for time sync)	❌ Not included / Optional Module
Power Usage	♻️ ~0.6W Low Power	🔌 ~2.2W Higher Power
Customizability	✅ Full Hardware/Software	❌ Limited
Target Users	Researchers, Makers, Engineers	General Users, Schools

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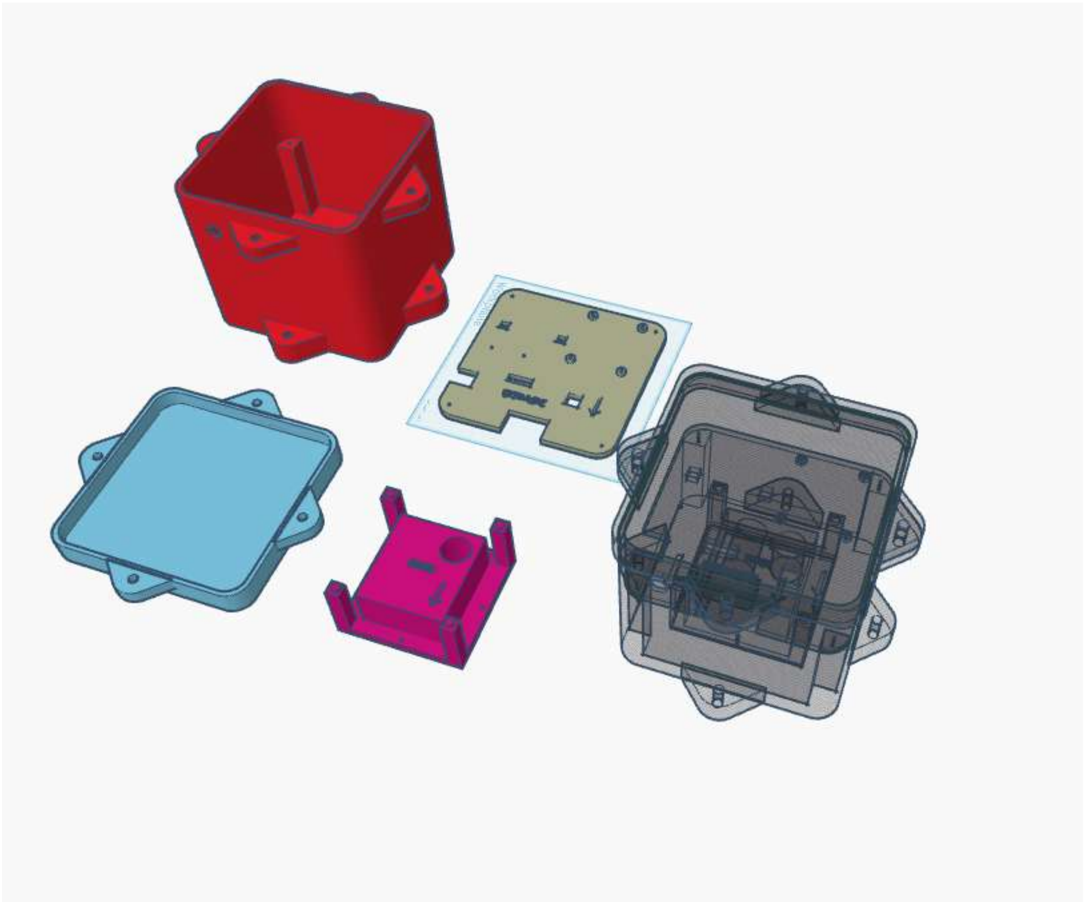

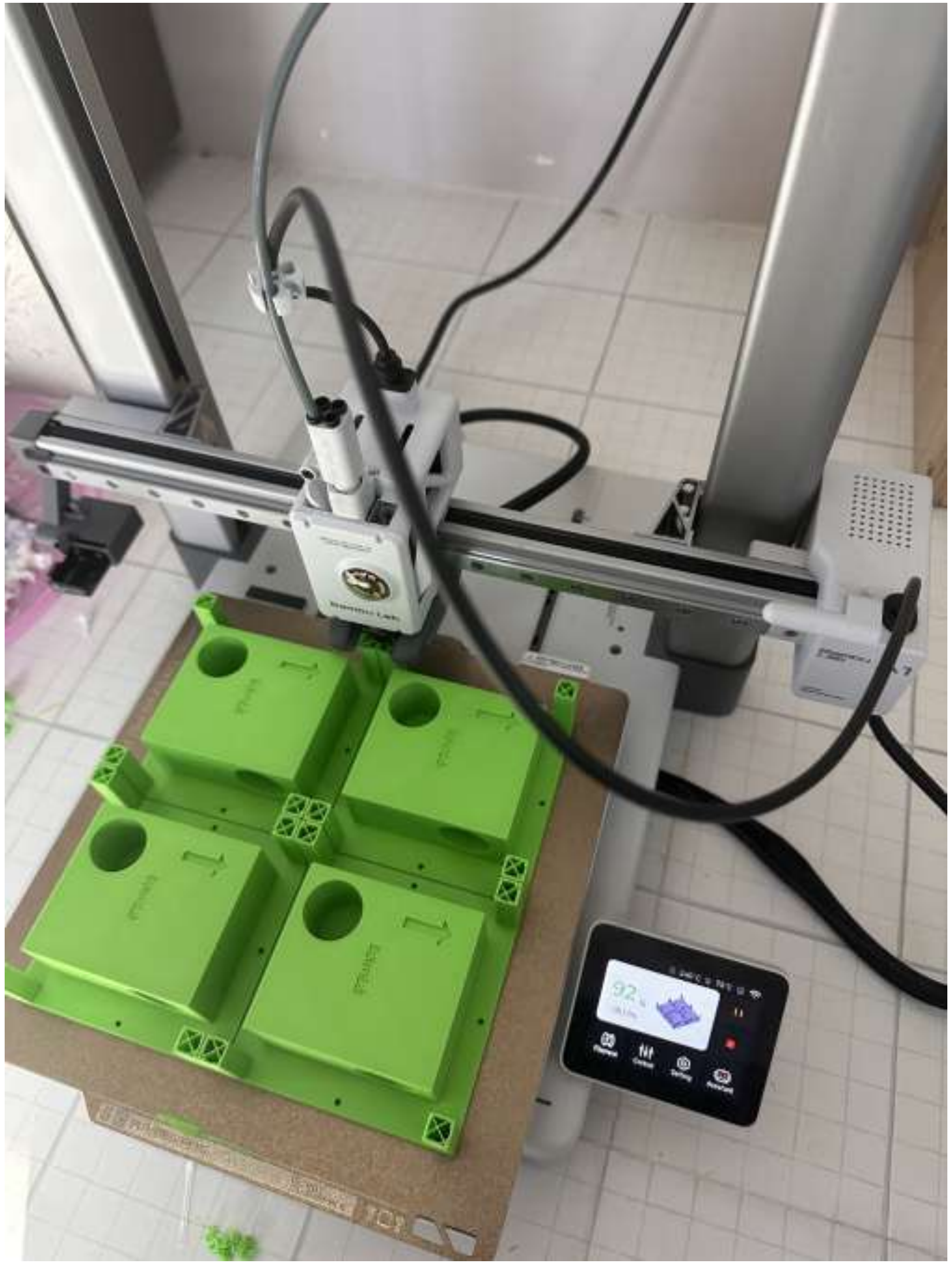

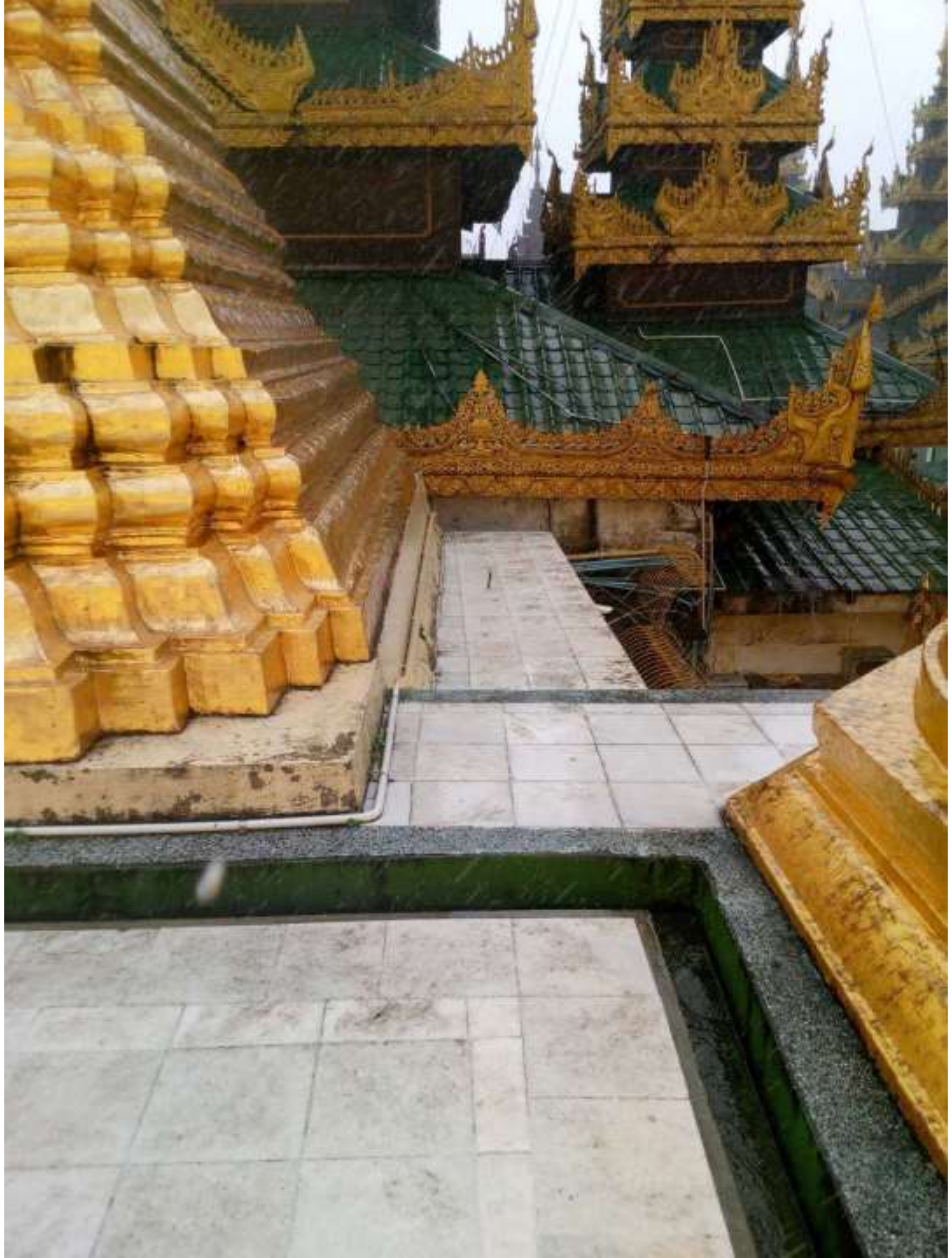




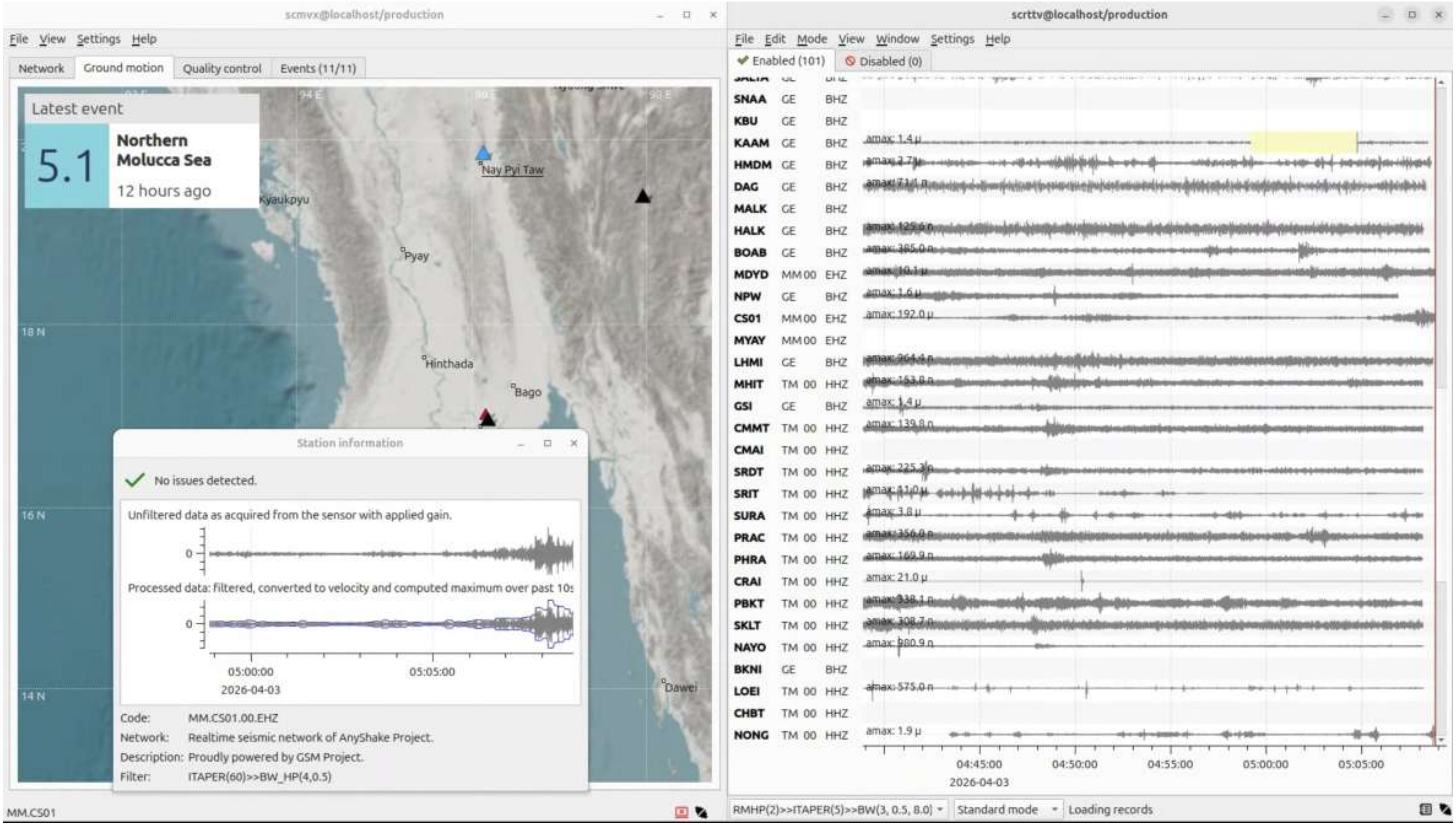
scmvx@localhost/production
File View Settings Help
Network
Ground motion
Quality control
Events (11/11)
Latest event
5.1
Northern Molucca Sea
12 hours ago
Nay Pyi Taw
Kyaukpyu
Pyay
18 N
Hinthada
Bago
16 N
14 N
Dawei
Station information
No issues detected.
Unfiltered data as acquired from the sensor with applied gain.
Processed data: filtered, converted to velocity and computed maximum over past 10s
05:00:00
2026-04-03
05:05:00
Code: MM.CS01.00.EHZ
Network: Realtime seismic network of AnyShake Project.
Description: Proudly powered by GSM Project.
Filter: ITAPER(60)>>BW_HP(4,0.5)
MM.CS01
scrttv@localhost/production
File Edit Mode View Window Settings Help
Enabled (101)
Disabled (0)
SNAA GE BHZ
KBU GE BHZ
KAAM GE BHZ
HMDM GE BHZ
DAG GE BHZ
MALK GE BHZ
HALK GE BHZ
BOAB GE BHZ
MDYD MM 00 EHZ
NPW GE BHZ
CS01 MM 00 EHZ
MYAY MM 00 EHZ
LHMI GE BHZ
MHIT TM 00 HHZ
GSI GE BHZ
CMMT TM 00 HHZ
CMAI TM 00 HHZ
SRDT TM 00 HHZ
SRIT TM 00 HHZ
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PHRA TM 00 HHZ
CRAI TM 00 HHZ
PBKT TM 00 HHZ
SKLT TM 00 HHZ
NAYO TM 00 HHZ
BKNI GE BHZ
LOEI TM 00 HHZ
CHBT TM 00 HHZ
NONG TM 00 HHZ
amax: 1.4 µ
amax: 192.0 µ
amax: 21.0 µ
amax: 575.0 n
amax: 1.9 µ
04:45:00
04:50:00
04:55:00
05:00:00
05:05:00
2026-04-03
RMHP(2)>>ITAPER(5)>>BW(3, 0.5, 8.0)
Standard mode
Loading records

What We Deployed (Overview)

Multi-Sensor Deployment

Low-cost seismic stations (AnyShake)

Low-cost CORS GNSS system

Creepmeter (fault motion monitoring)

Integration with existing Raspberry Shake network

Seismic Network Support

Seismic Stations Deployment

3 × AnyShake instruments

Mandalay (near source region)

Shwedagon Pagoda (Yangon reference site)

Mingaladon

Complement existing **Raspberry Shake network**

Improve spatial coverage & detection capability

GNSS Monitoring (Sagaing Fault)

Low-Cost GNSS Deployment

Modified low-cost CORS GNSS system

Installed near Sagaing Fault

Continuous observation capability

Designed for **tectonic deformation monitoring**


MPPT
SOLAR CHARGE CONTROLLER

Creepmeter Installation

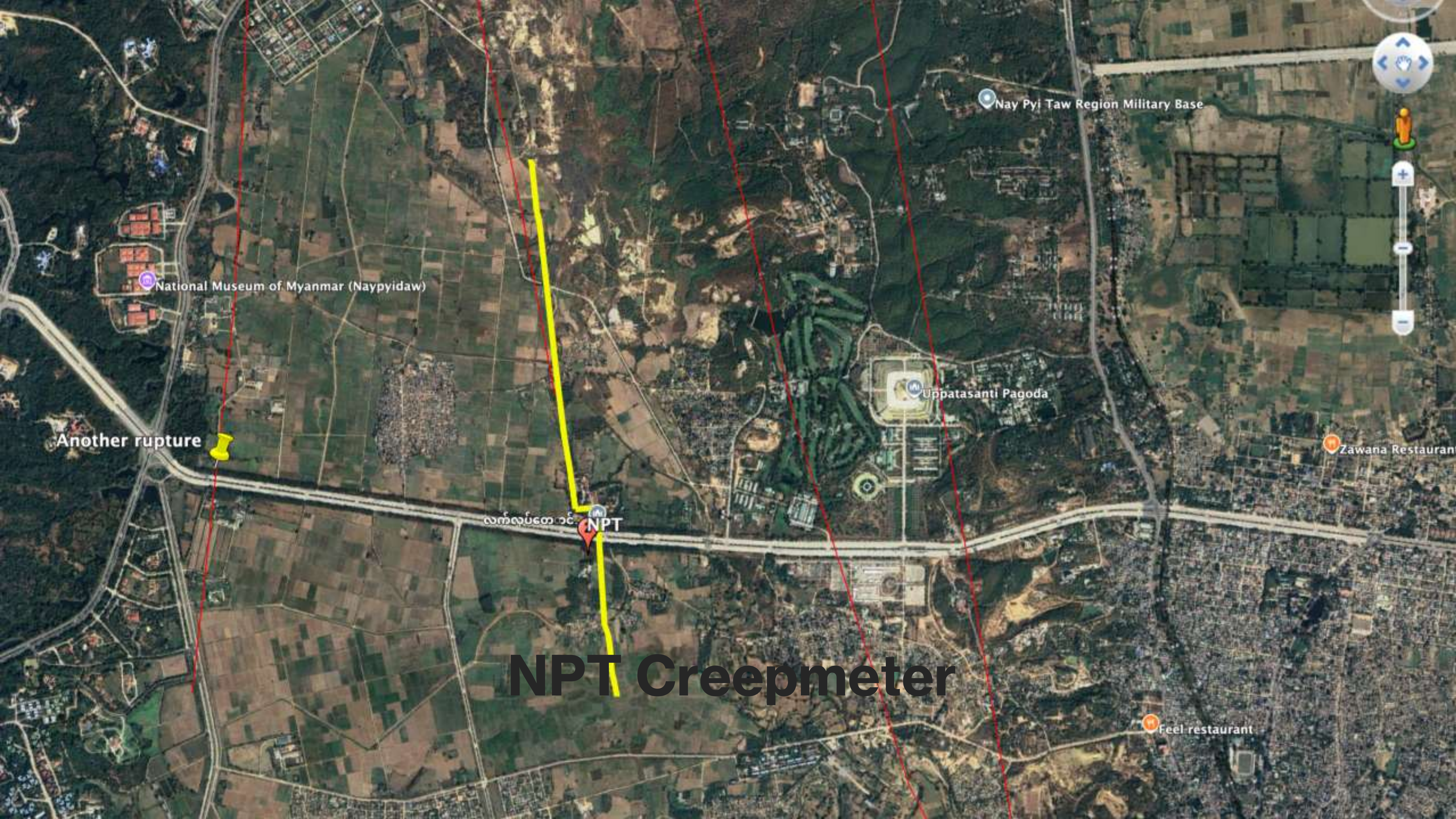
Fault Motion Monitoring

Installed creepmeter across fault zone

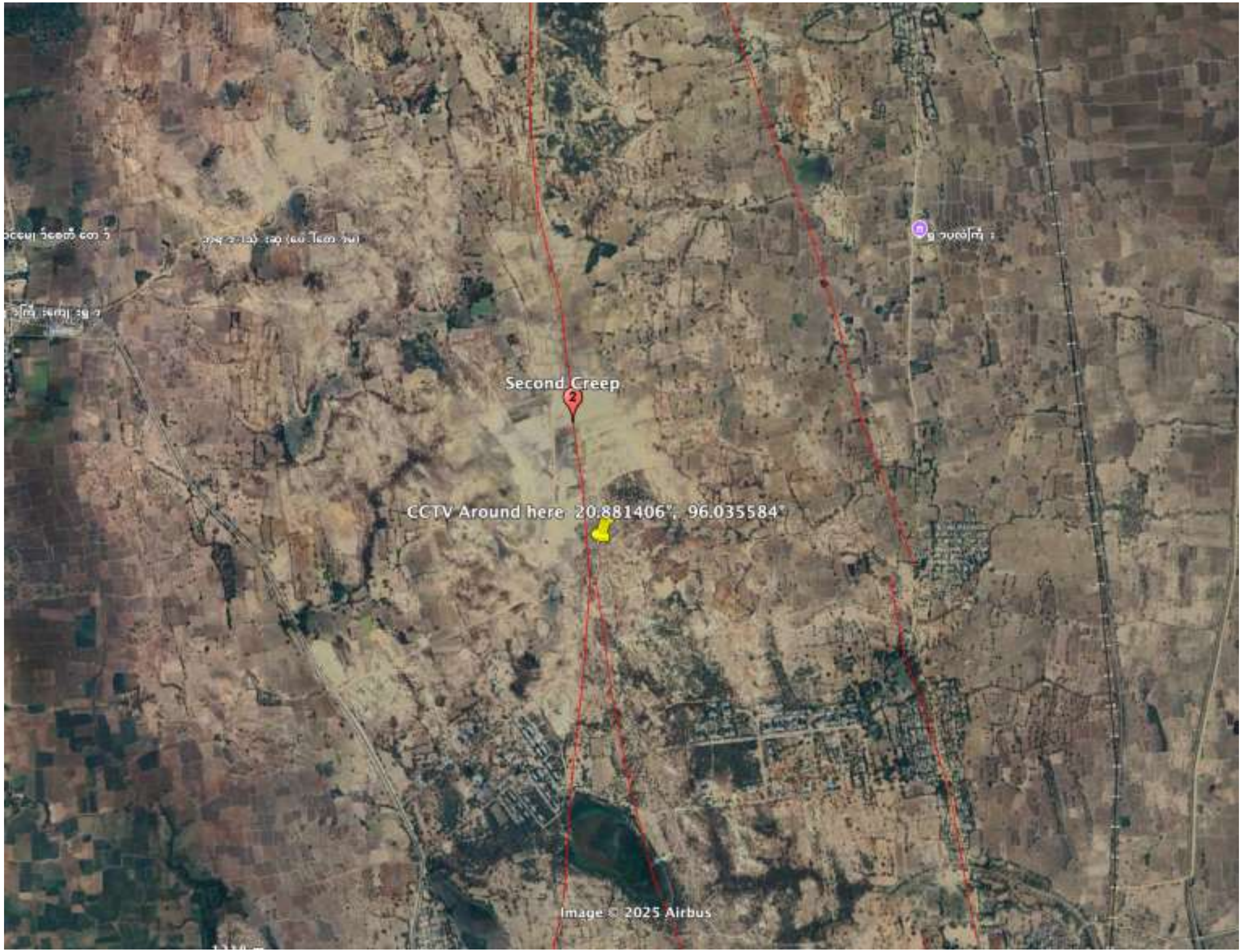
Captures **near-field deformation (creep)**

High temporal resolution measurements


2025/09/26 11:40


Nay Pyi Taw Region Military Base
National Museum of Myanmar (Naypyidaw)
Uppatasanti Pagoda
Another rupture
Zawana Restaurant
လက်လှပ်တောင်
NPT
NPT Creepmeter
Feel restaurant

Second Creepmeter



NPT: ~3 months of usable data

→ ~8 mm afterslip observed

SA3 (Tharzi): ~7 months of high-quality data

→ ~10 mm afterslip (ongoing)

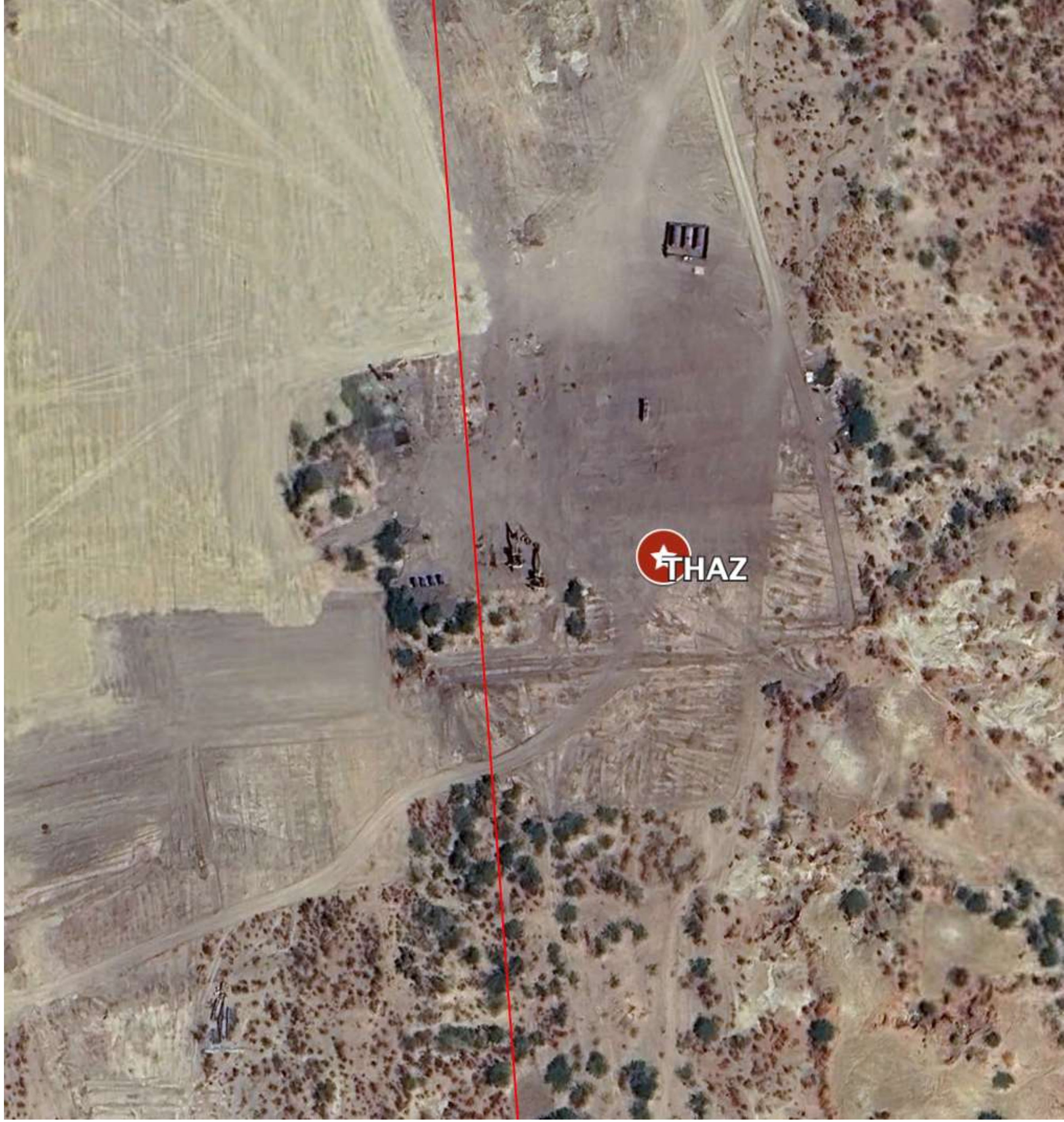
Data Examples (GNSS)

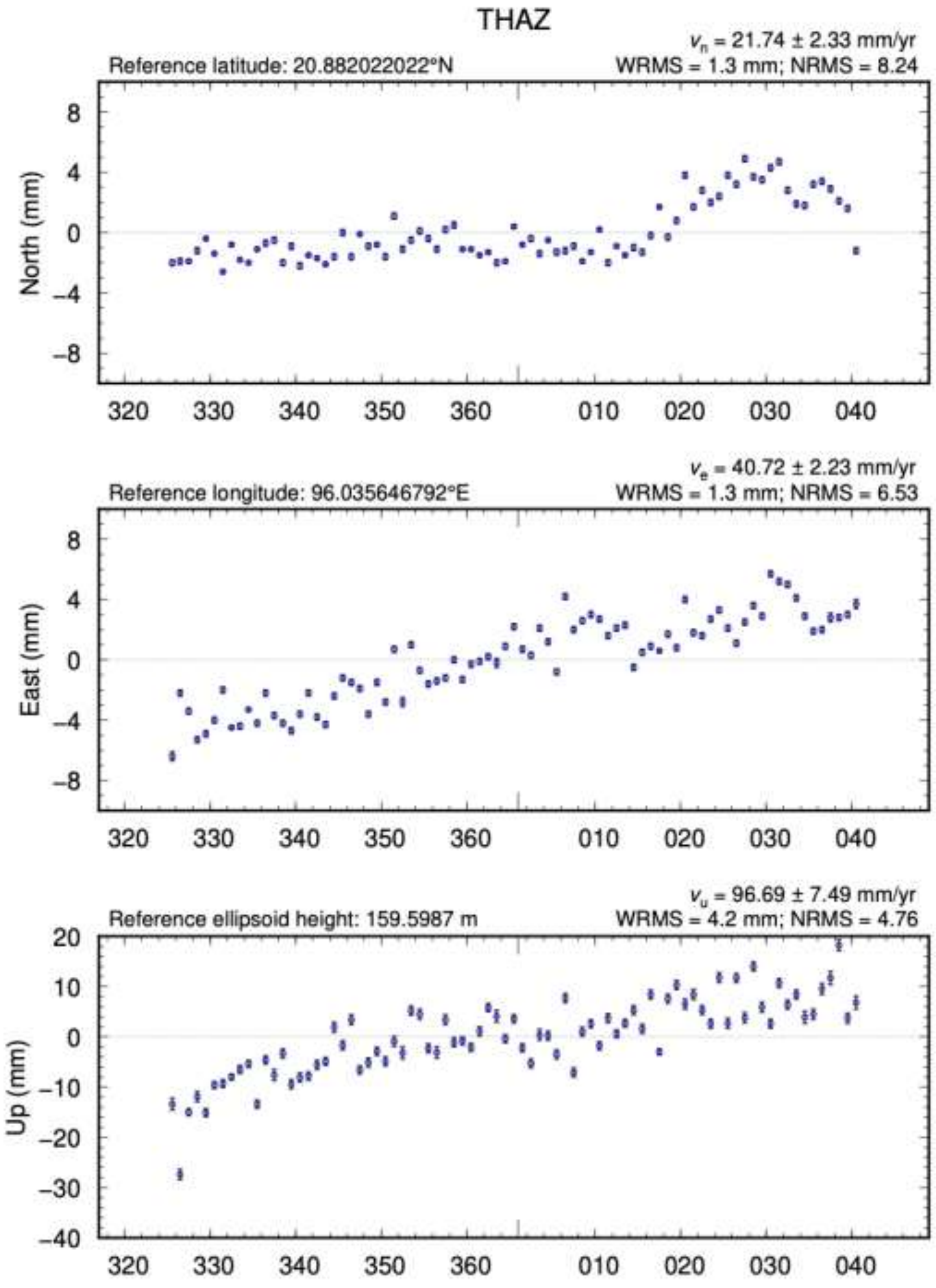
GNSS Time Series (Tharzi Station)

Show displacement time series (E/N/U)

Data continuity and noise level

Demonstrates system capability




THAZ
v_n = 21.74 ± 2.33 mm/yr
Reference latitude: 20.882022022°N
WRMS = 1.3 mm; NRMS = 8.24
North (mm)
v_e = 40.72 ± 2.23 mm/yr
Reference longitude: 96.035646792°E
WRMS = 1.3 mm; NRMS = 6.53
East (mm)
v_u = 96.69 ± 7.49 mm/yr
Reference ellipsoid height: 159.5987 m
WRMS = 4.2 mm; NRMS = 4.76
Up (mm)
320 330 340 350 360 010 020 030 040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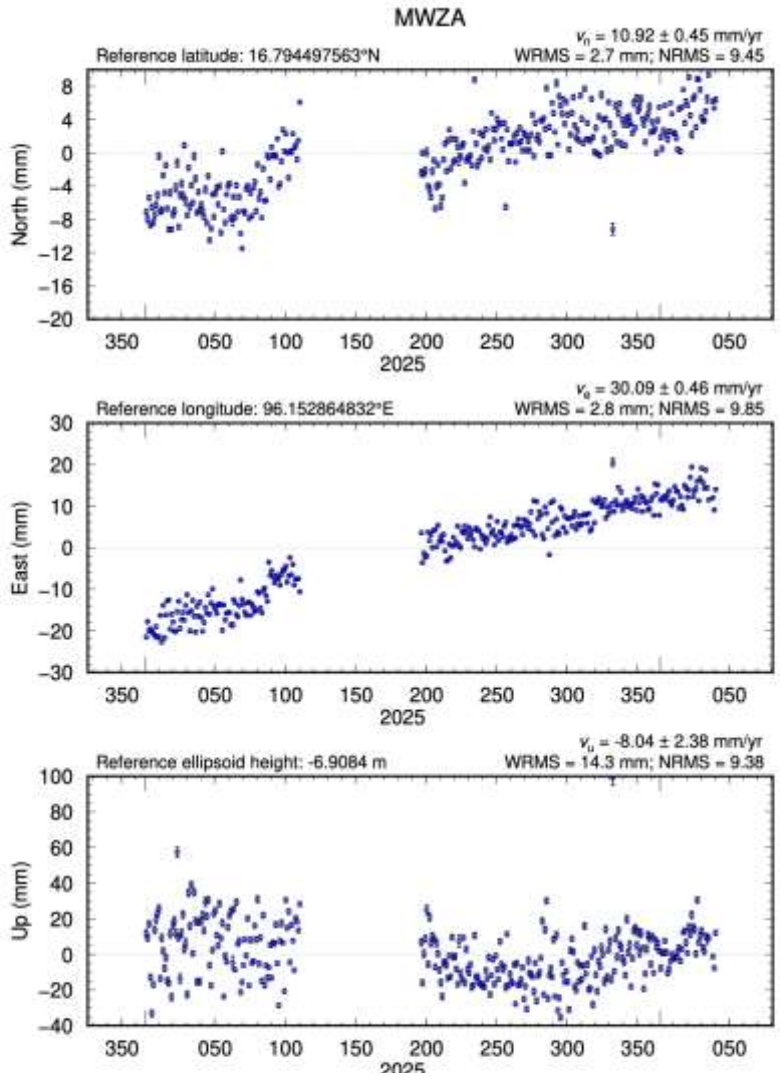
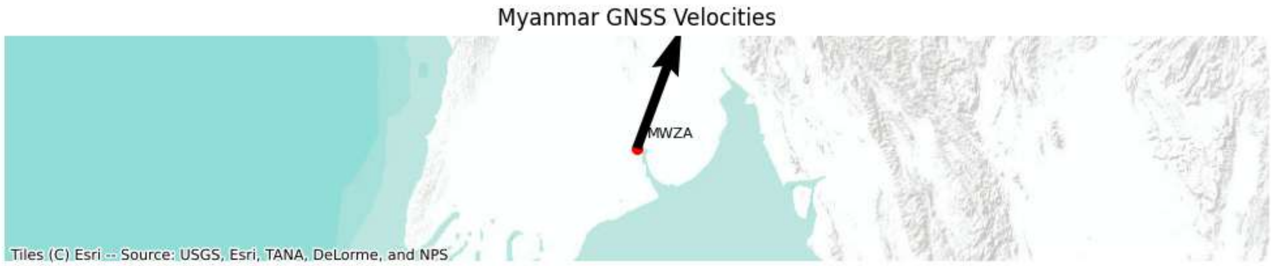
မြေငလျင်ဖြတ်သန်းသွားသောလမ်းကြောင်း
ပြတ်ရွေ့အကျယ်=(၉)ပေ

Data Examples (Seismic & Geodetic Waveforms)

Waveform Demonstration

MWZA GNSS-derived waveform





Key Takeaways (No Over-Conclusion)

Key Observations

Rapid deployment is feasible with low-cost systems

Multi-sensor setup improves monitoring capability

Data quality is sufficient for further analysis

Next Steps

Expand network along Sagaing Fault

Integrate seismic + GNSS + creep data

Develop real-time monitoring and alerts