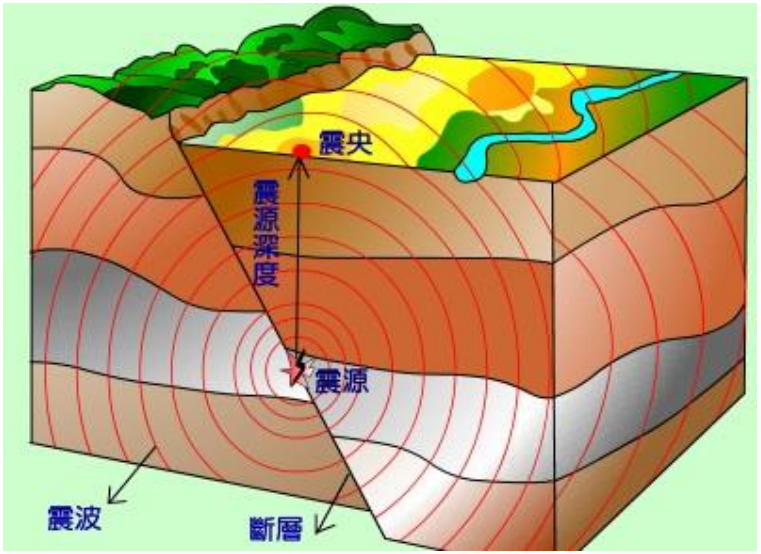
20 YEARS SEMICON® Taiwan 2015

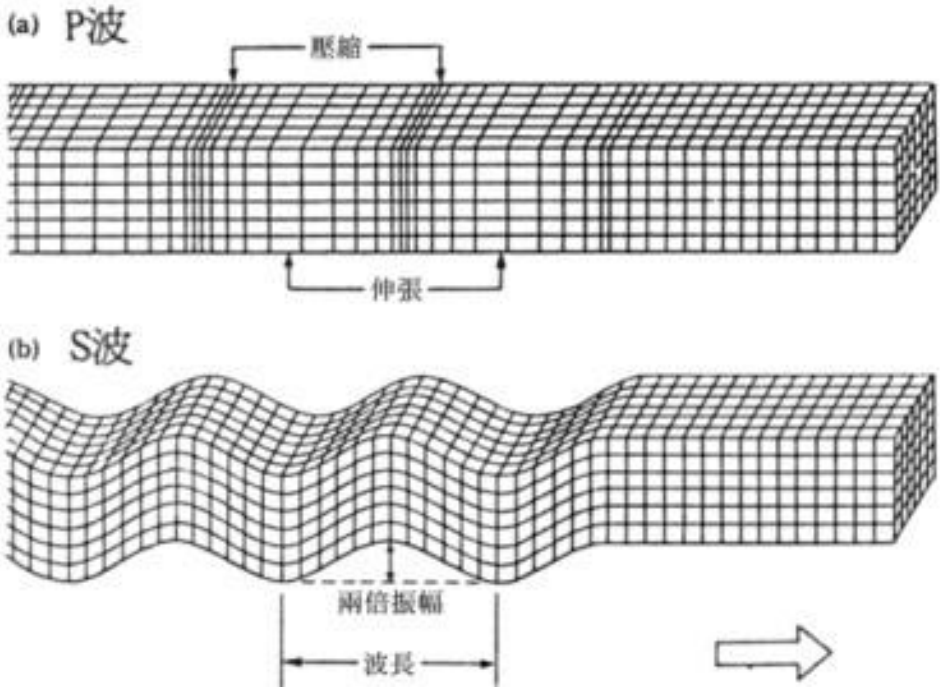
Development and Application of Earthquake Early Warning System in NCREE

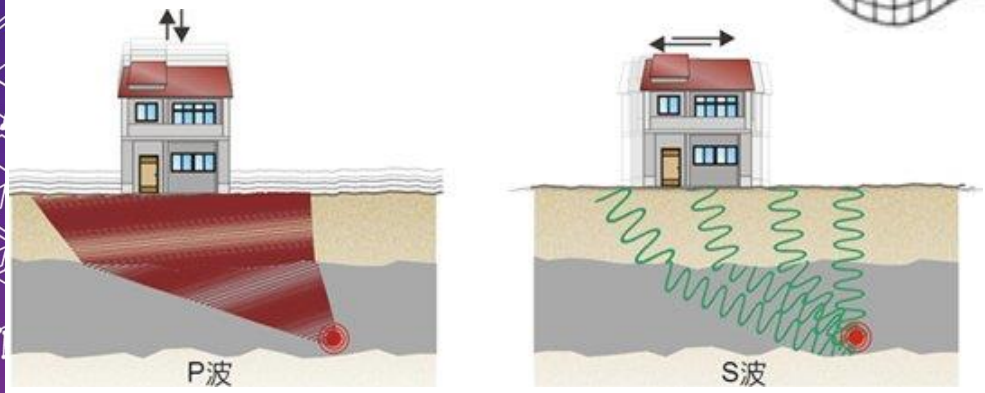
P.Y. Lin, T.Y. Hsu & H.W. Jiang

NARLabs 國家實驗研究院 National Applied Research Laboratories

Introduction of earthquake wave



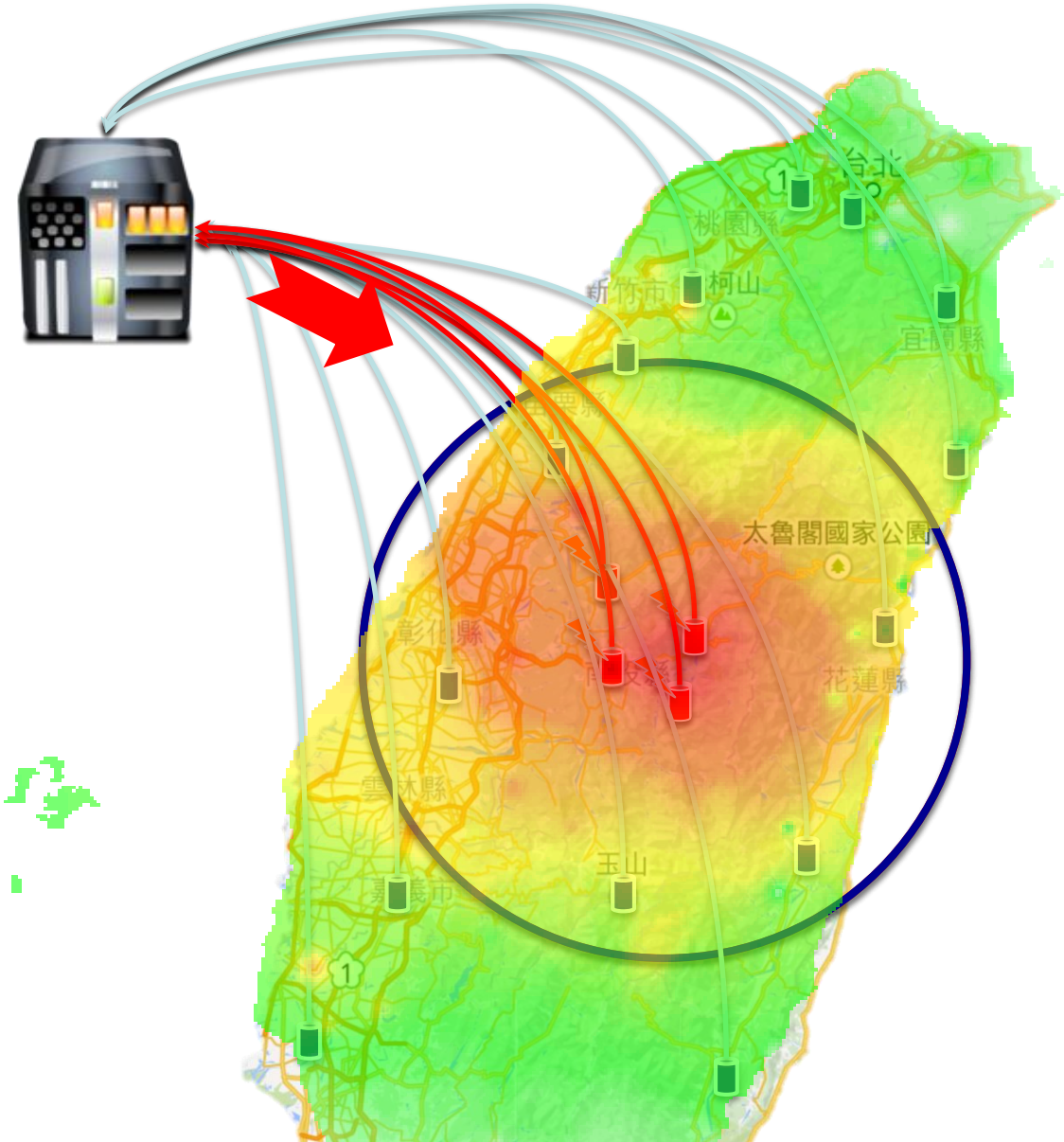




- P Wave (primary wave)： 6 ~ 7 km/s
- S Wave (shear wave or secondary wave)：3 ~ 4 km/s

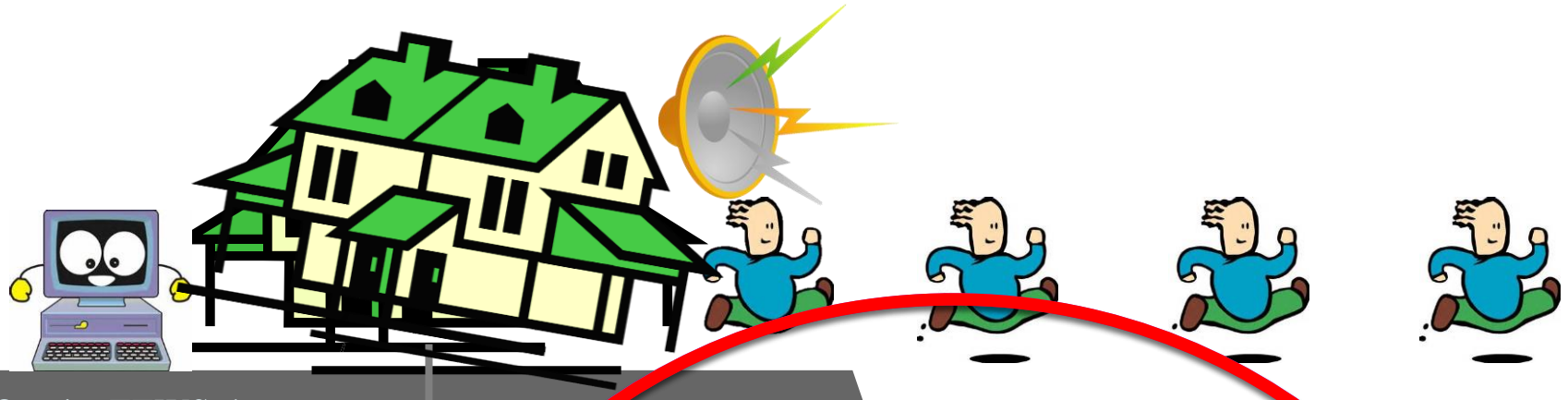
Two Types of EEWS

- Regional EEWS



Two Types of EEWS

- On-site EEWS



On-site EEWS detect P wave, then predict the seismic intensity.

If predicted intensity higher than threshold, raise alarm.

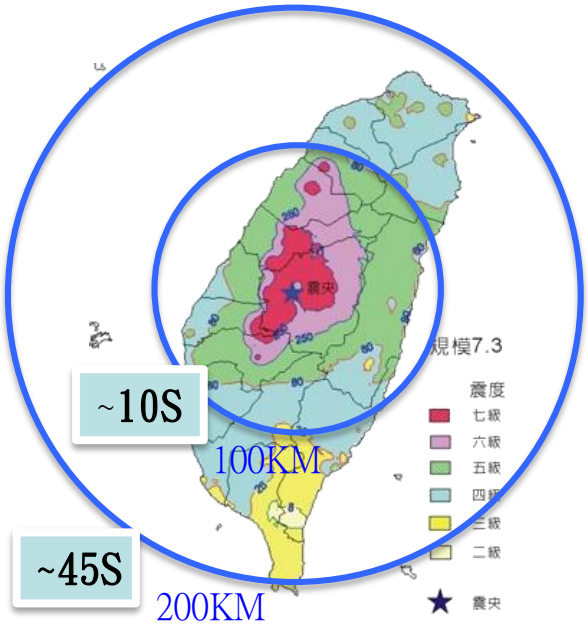
P-wave：6~7km/s
S-wave：3~4km/s

Epicener

311 Earthquake in Japan

Epicenter was far from city
Long warning time

921 Earthquake in Taiwan



Epicenter was close to city
Short Warning Time

On-site EEW
Support Vector Regression(SVR)

2013 Ting-Yu Hsu et al.

Earthquake Data
(CWB Database)

Six P-wave features

Real PGA

Training

Regression Model

Prediction Accuracy Rate(PAR):99.22%
(CWB Validation)

Features

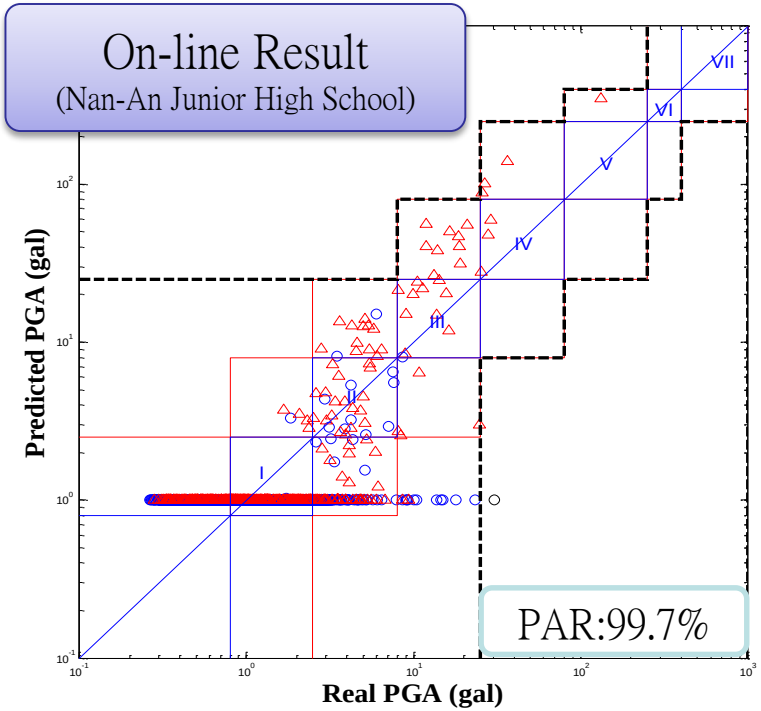
- Pa
- Pv
- Pd
- CAV
- IV2
- TauC

$$\text{CAV}: \int_0^3 |\ddot{u}(t)|dt$$

$$\text{IV2}: \int_0^3 |\dot{u}^2(t)|dt$$

$$\text{TauC}: 2\pi/\sqrt{r} \quad \left(r = \int_0^3 \dot{u}^2(t)dt \Big/ \int_0^3 u^2(t)dt\right)$$

On-line Result
(Nan-An Junior High School)



Integration Test of On-site Earthquake Early Warning System

ChiChi Earthquake
- Time : 88/9/21 1:47
- Depth : 8 km
- Magnitude : 7.3

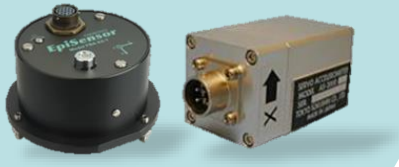
Photo of the press conference of the integration test on the shaking table on 2,22,2011

EEWS for Schools

EEWS Demonstration Station : Regional + On-site EEWS

NCREE

On-site Sensor



CWB

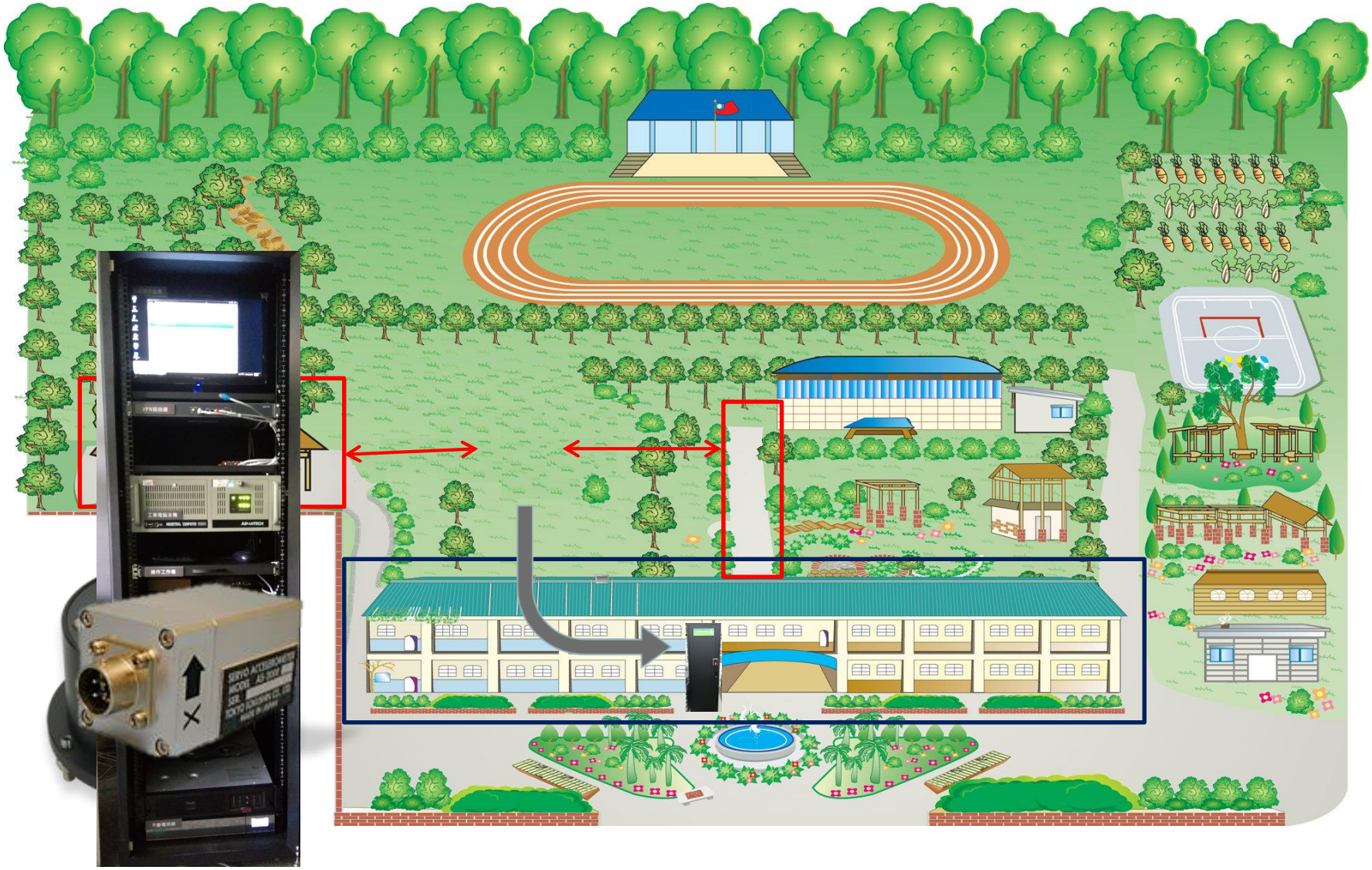
Regional EEWS Message

EEW LED Display

EEW Broadcast

E-mail
SMS Message

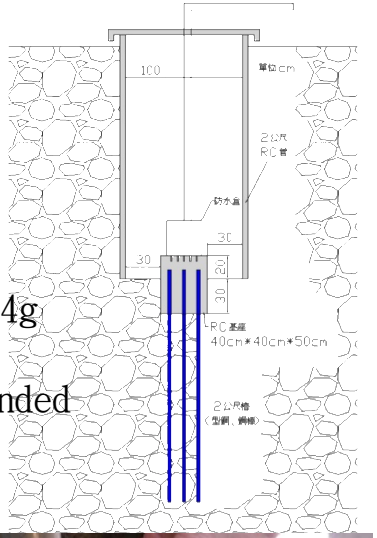
Typical System Arrangement of On-site EEWS for School



Installation of Shallow down hole Sensor

Kinemetrics EpiSensor ES-T

Dynamic range: 155 dB+
Bandwidth: DC to 200Hz
Full-scale range:
User selectable at ± 0.25g, ± 0.5g, ± 1g, ± 2g or ± 4g
Outputs:
User selectable at:± 2.5V single-ended± 10V single-ended
± 5V differential ± 20V differential

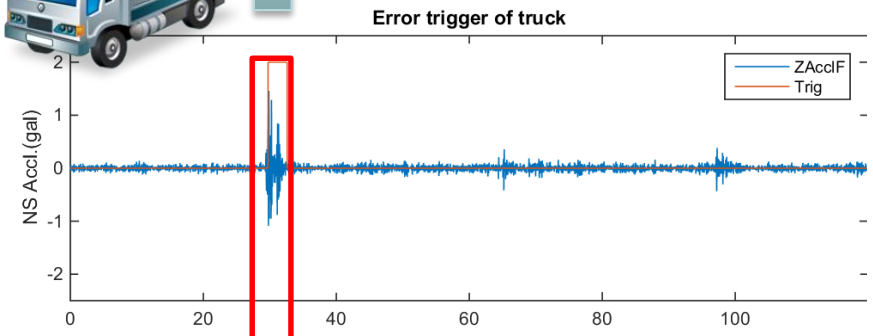


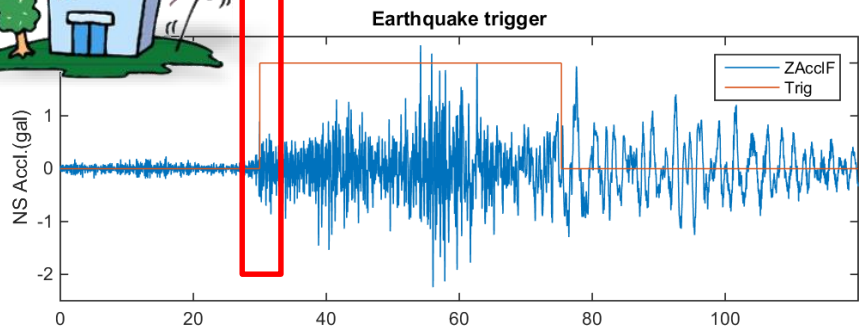
Installation of Backup Sensor on structure

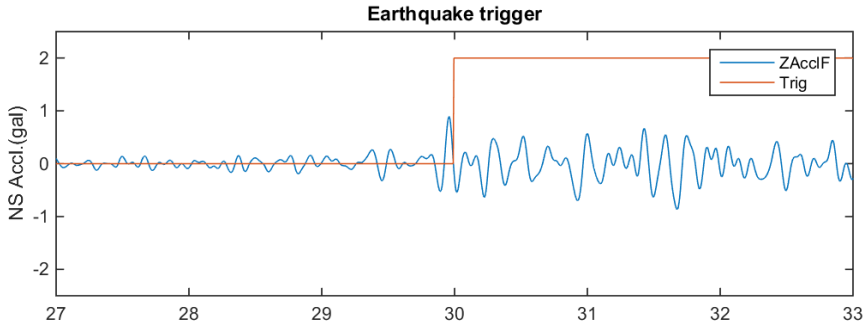
AS-305C1W5 Sensor
Dynamic range: 155 dB+
Bandwidth: DC to 250Hz
Full-scale range: User selectable at ± 2000gal
Scale Factor: 5mv/gal

Problem in Real World

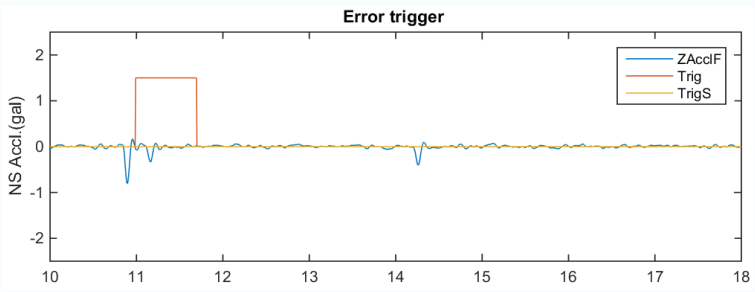
How to mitigate the false alarm

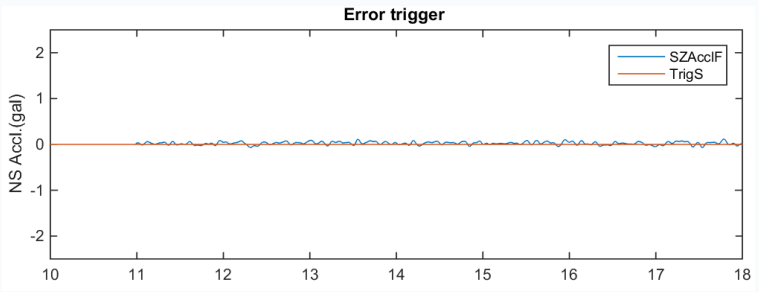


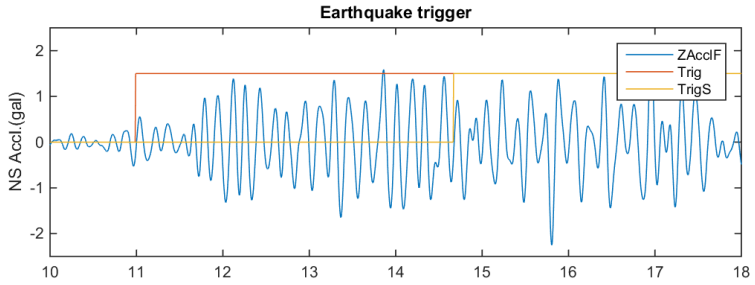


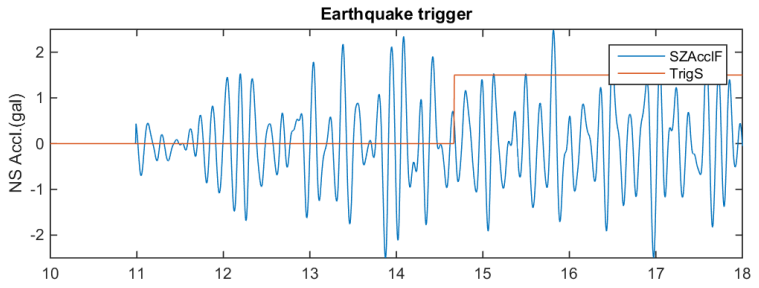


Application of Backup Sensor



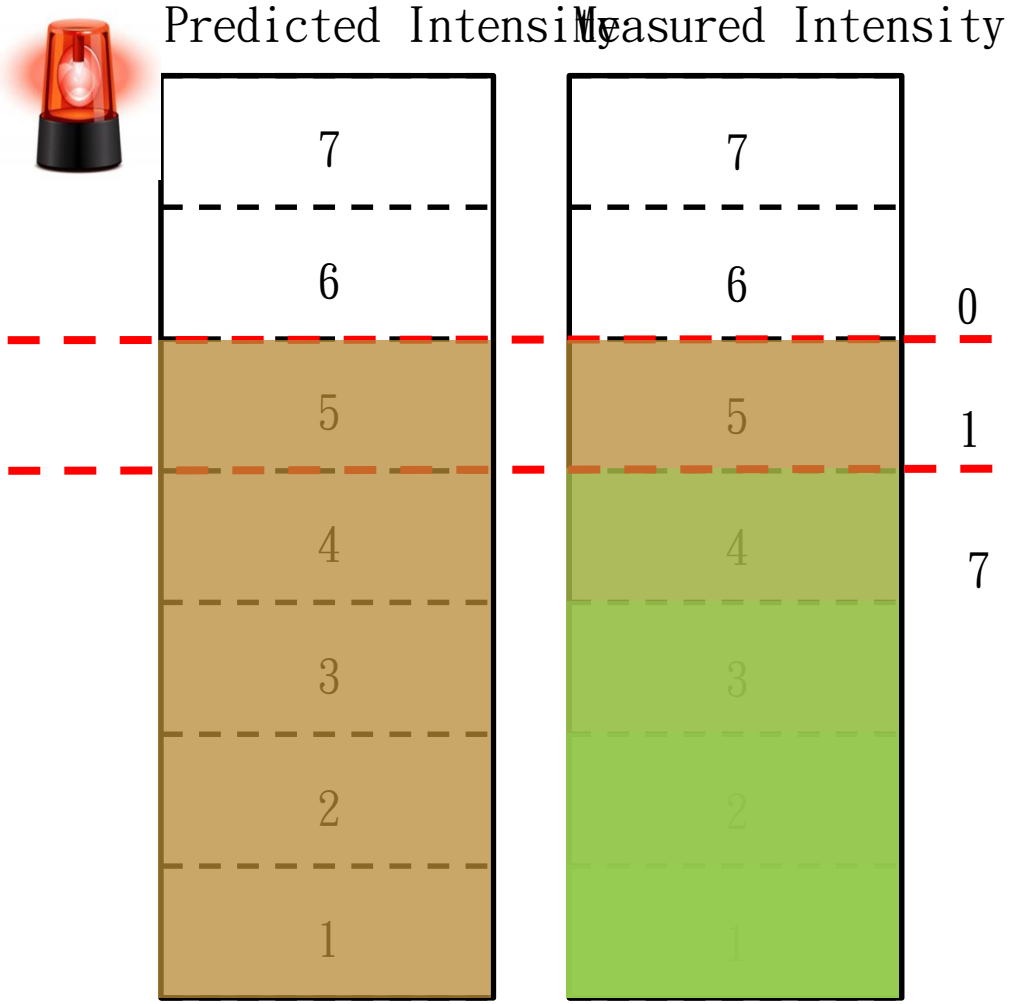


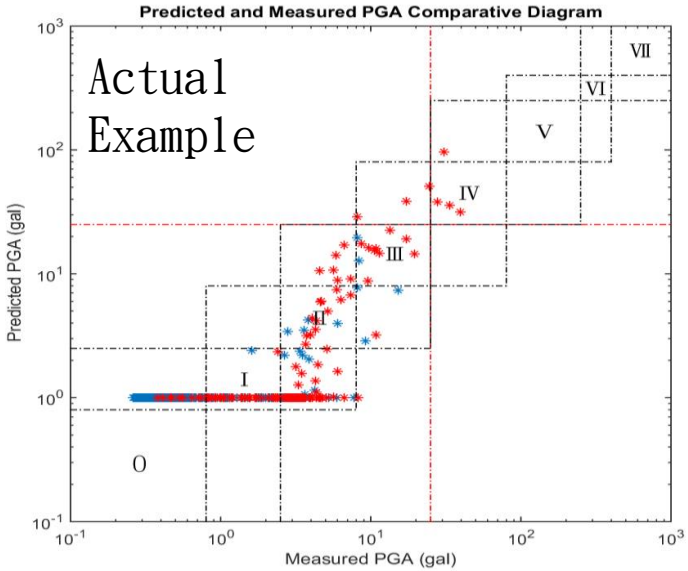




Nan'an junior high school
2014.07.01~2015.06.30

Threshold can change





Predicted Intensity	Number of times (year)
Over 5 class	0
Over 4 class	1
Over 3 class	7

On-site EEWS detects the earthquake P-wave, and then predicted seismic inte

Education and Drill for Schools

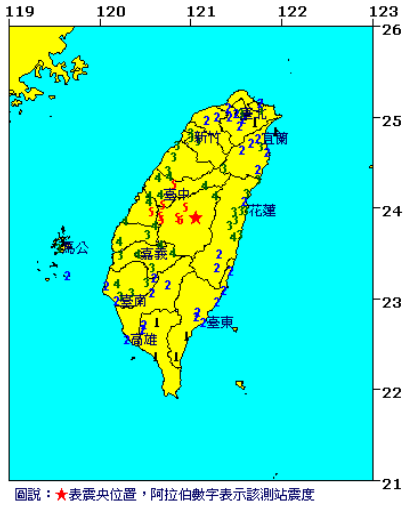
- Education of Seismic Disaster Reduction
- Seismic Disaster Prevention Drill

In School – when earthquake is coming…

Video:
Earthquake Disaster Prevention Drill

Success EEW case - 2013/3/27 港坪國小

- Epicenter distance：~60km



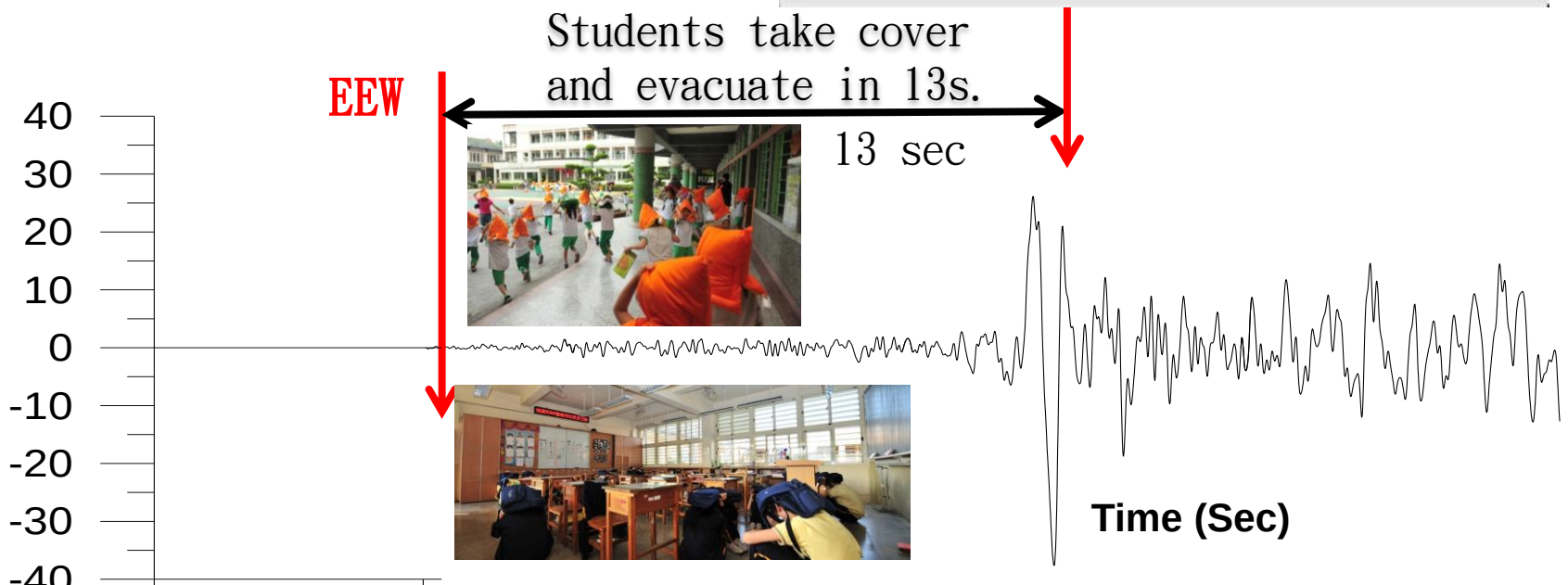
圖說：★表震央位置，阿拉伯數字表示該測站震度

中 央 氣 象 局 地 震 報 告

編號： 第102041號
日期： 102 年 3 月 27 日
時間： 10 時 3 分 19.7 秒
位置： 北緯 23.9 度，東經 121.07 度
即在 南投縣政府東方 38.8 公里
位於 南投縣仁愛鄉
地震深度： 15.4 公里
芮氏規模： 6.1
各地最大震度

南投縣日月潭	6級	新竹縣竹東	3級
南投縣南投市	5級	新竹市	3級
臺中市霧峰	5級	新竹縣竹北市	3級
彰化縣員林	5級	臺北市信義區	3級
花蓮縣光復	4級	新北市五分山	3級
臺中市	4級	澎湖縣馬公市	3級
嘉義縣阿里山	4級	臺東縣長濱	2級
雲林縣草嶺	4級	高雄市桃源	2級
彰化縣彰化市	4級	宜蘭縣宜蘭市	2級
苗栗縣鯉魚潭	4級	桃園縣中壢	2級
嘉義市	4級	桃園縣桃園市	2級
臺南市佳里	4級	臺東縣臺東市	2級
花蓮縣花蓮市	3級	新北市	2級
雲林縣斗六市	3級	臺北市	2級
宜蘭縣南山	3級	臺南市	2級
苗栗縣苗栗市	3級	屏東縣九如	2級

本報告係中央氣象局地震觀測網即時地震資料地震速報之結果。

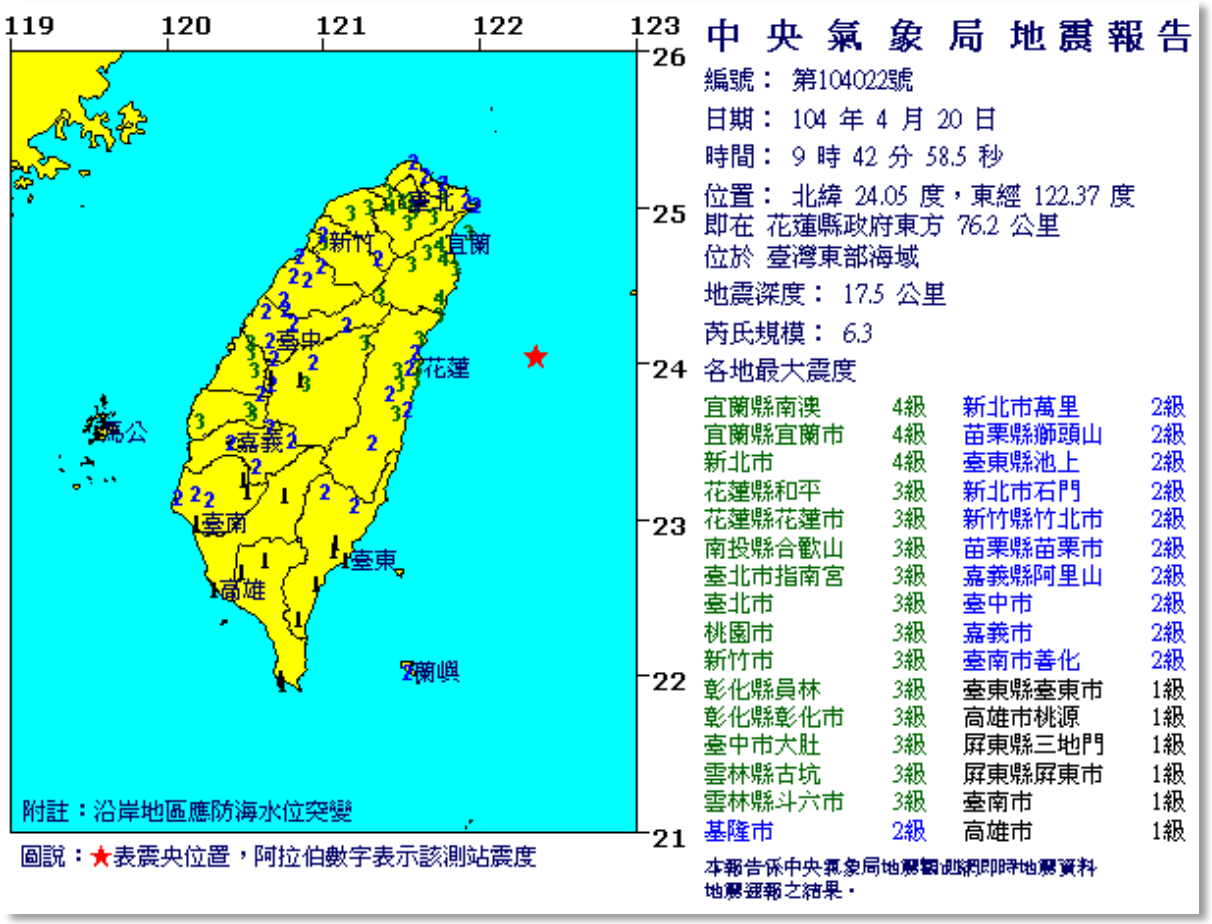


Validation in field

On-site EEWS developed by NCREE

NARLabs 國家實驗研究院
National Applied Research Laboratories

CWB Earthquake Report



圖說：★表震央位置，阿拉伯數字表示該測站震度

中 央 氣 象 局 地 震 報 告

編號： 第104022號

日期： 104 年 4 月 20 日

時間： 9 時 42 分 58.5 秒

位置： 北緯 24.05 度，東經 122.37 度
即在 花蓮縣政府東方 76.2 公里
位於 臺灣東部海域

地震深度： 17.5 公里

芮氏規模： 6.3

各地最大震度

宜蘭縣南澳	4級	新北市萬里	2級
宜蘭縣宜蘭市	4級	苗栗縣獅頭山	2級
新北市	4級	臺東縣池上	2級
花蓮縣和平	3級	新北市石門	2級
花蓮縣花蓮市	3級	新竹縣竹北市	2級
南投縣合歡山	3級	苗栗縣苗栗市	2級
臺北市指南宮	3級	嘉義縣阿里山	2級
臺北市	3級	臺中市	2級
桃園市	3級	嘉義市	2級
新竹市	3級	臺南市善化	2級
彰化縣員林	3級	臺東縣臺東市	1級
彰化縣彰化市	3級	高雄市桃源	1級
臺中市大肚	3級	屏東縣三地門	1級
雲林縣古坑	3級	屏東縣屏東市	1級
雲林縣斗六市	3級	臺南市	1級
基隆市	2級	高雄市	1級

本報告係中央氣象局地震觀測網即時地震資料地震速報之結果。

Earthquake No.: 104022

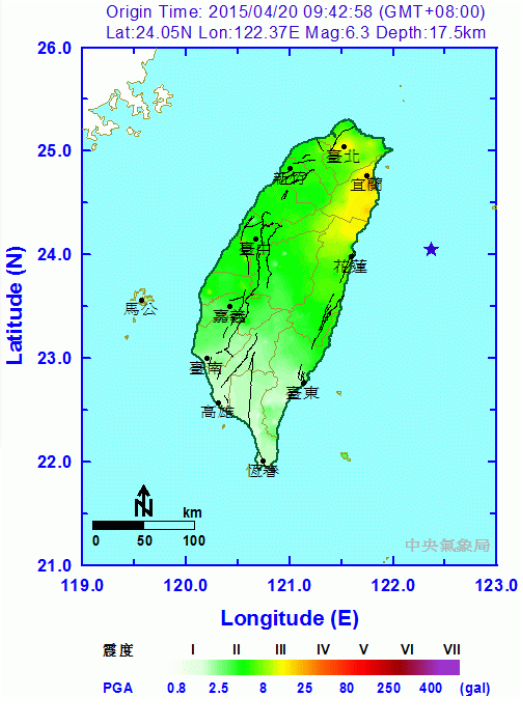
Origin time(Taiwan Time: GMT+08:00):

4/20/2015 09:42:58.5

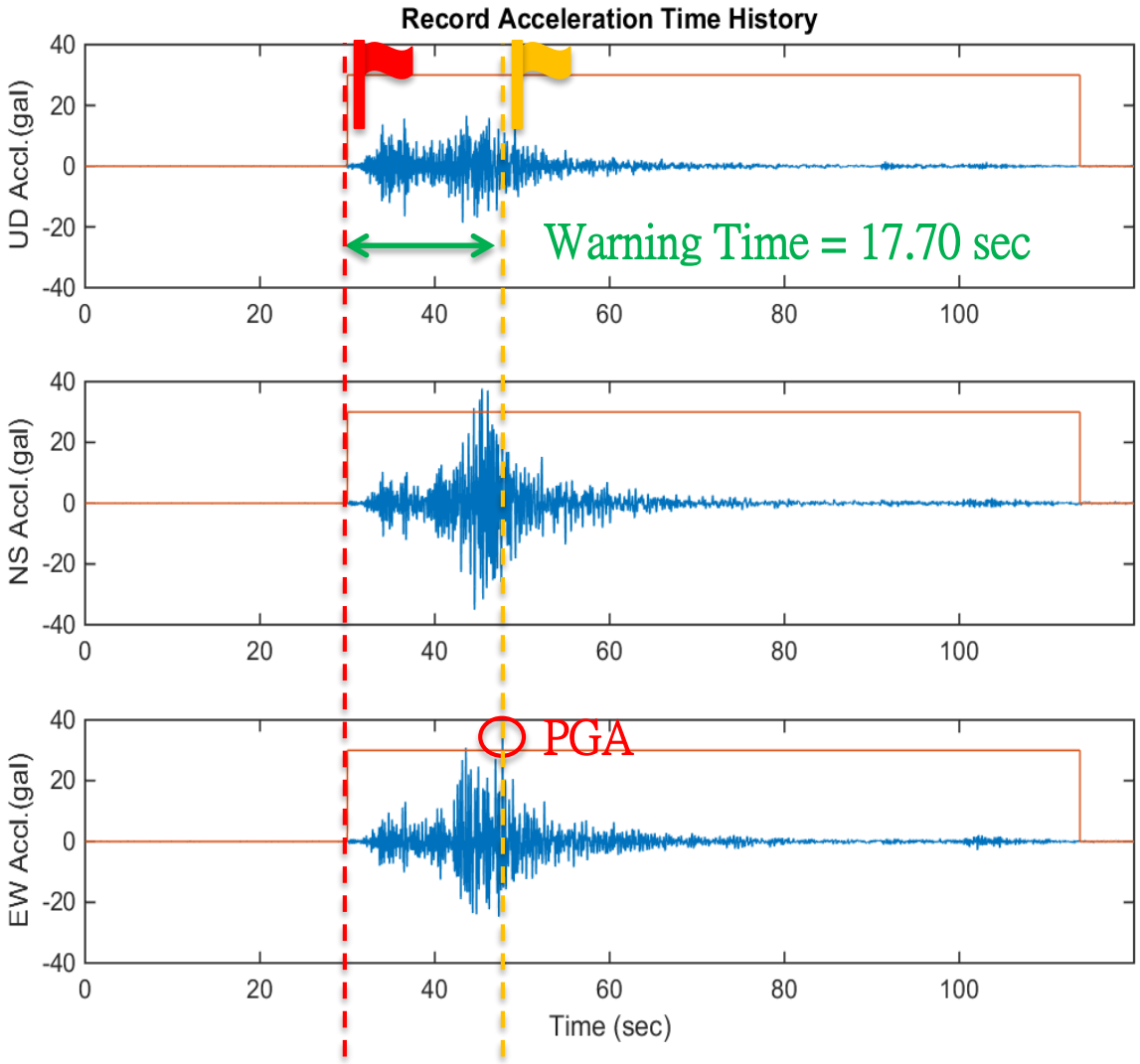
Location: 24.05N 122.37E

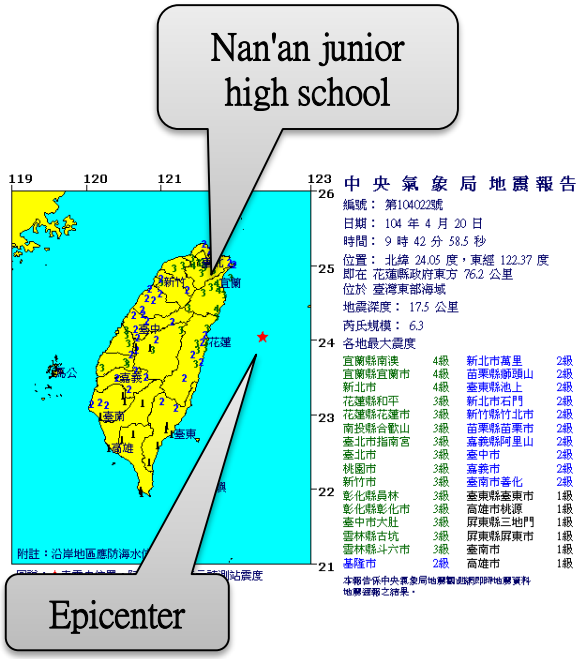
Depth: 17.5km

Magnitude(ML): 6.3



EEWS Station Response of Nan'an junior high school

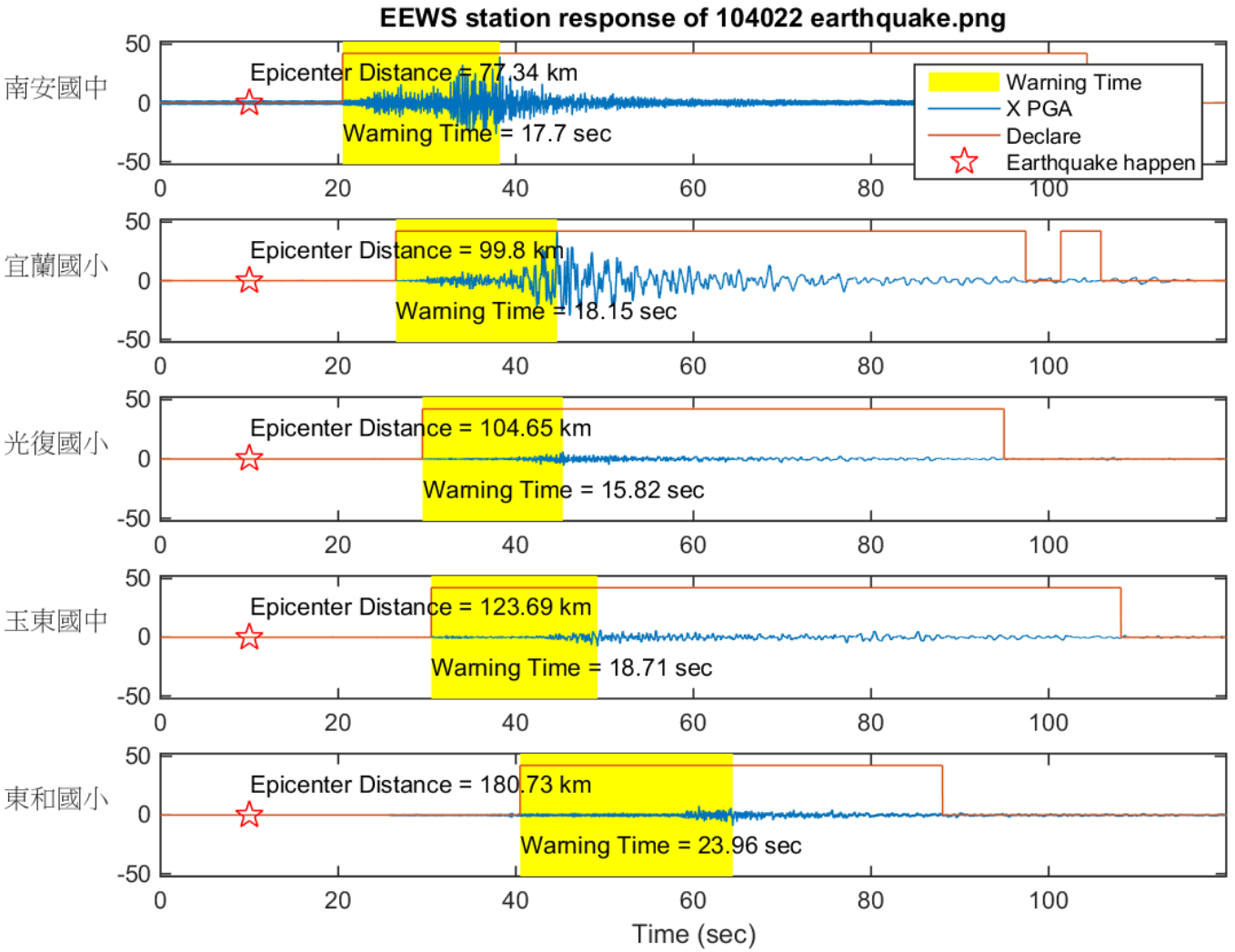




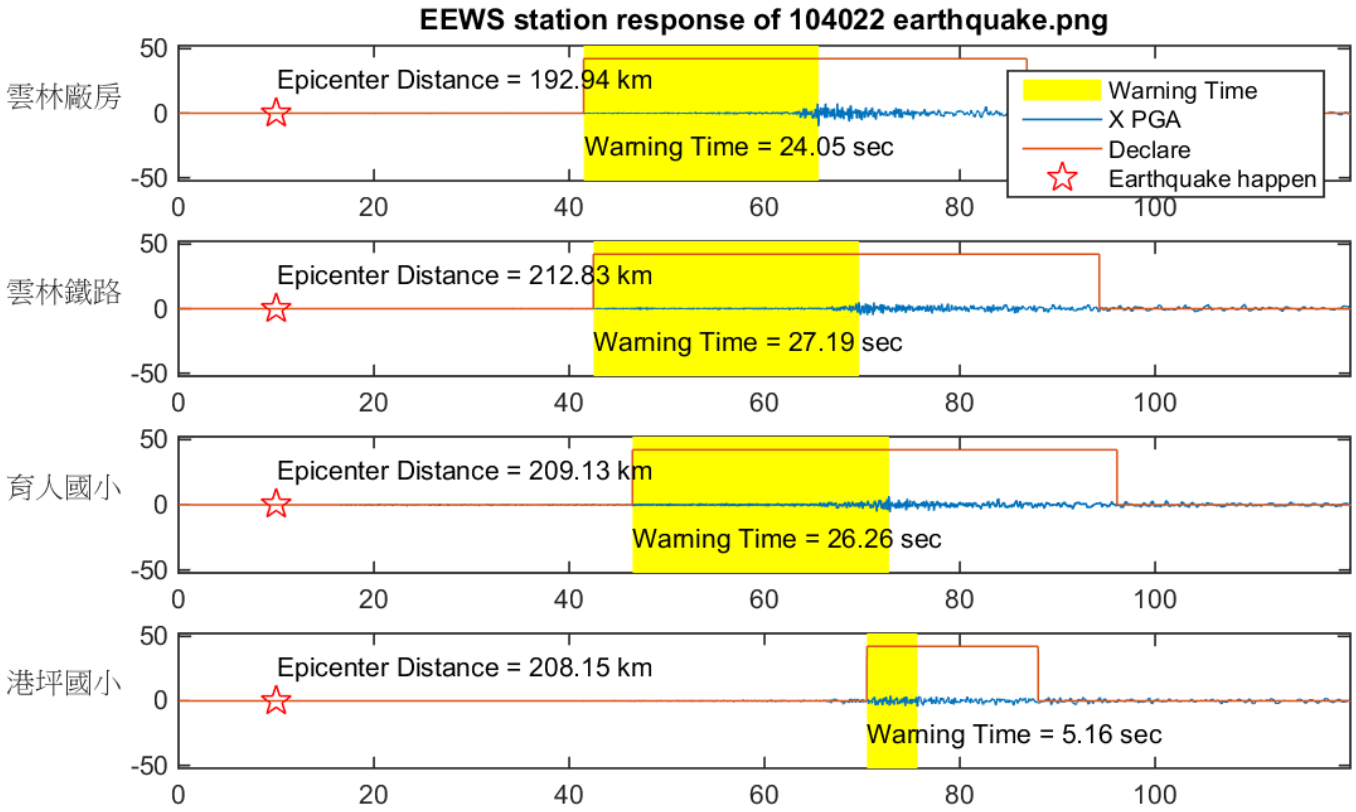
- Warning Time : 17.70 sec
- Epicenter Distance ≈ 77.34km

Performance	Online	Real
Intensity	4	4
PGA(gal)	31.57	39.67

EEWS Station Response of Earthquake No.104022



EEWS Station Response of Earthquake No.104022



EEWS Station Response of Earthquake No.104022

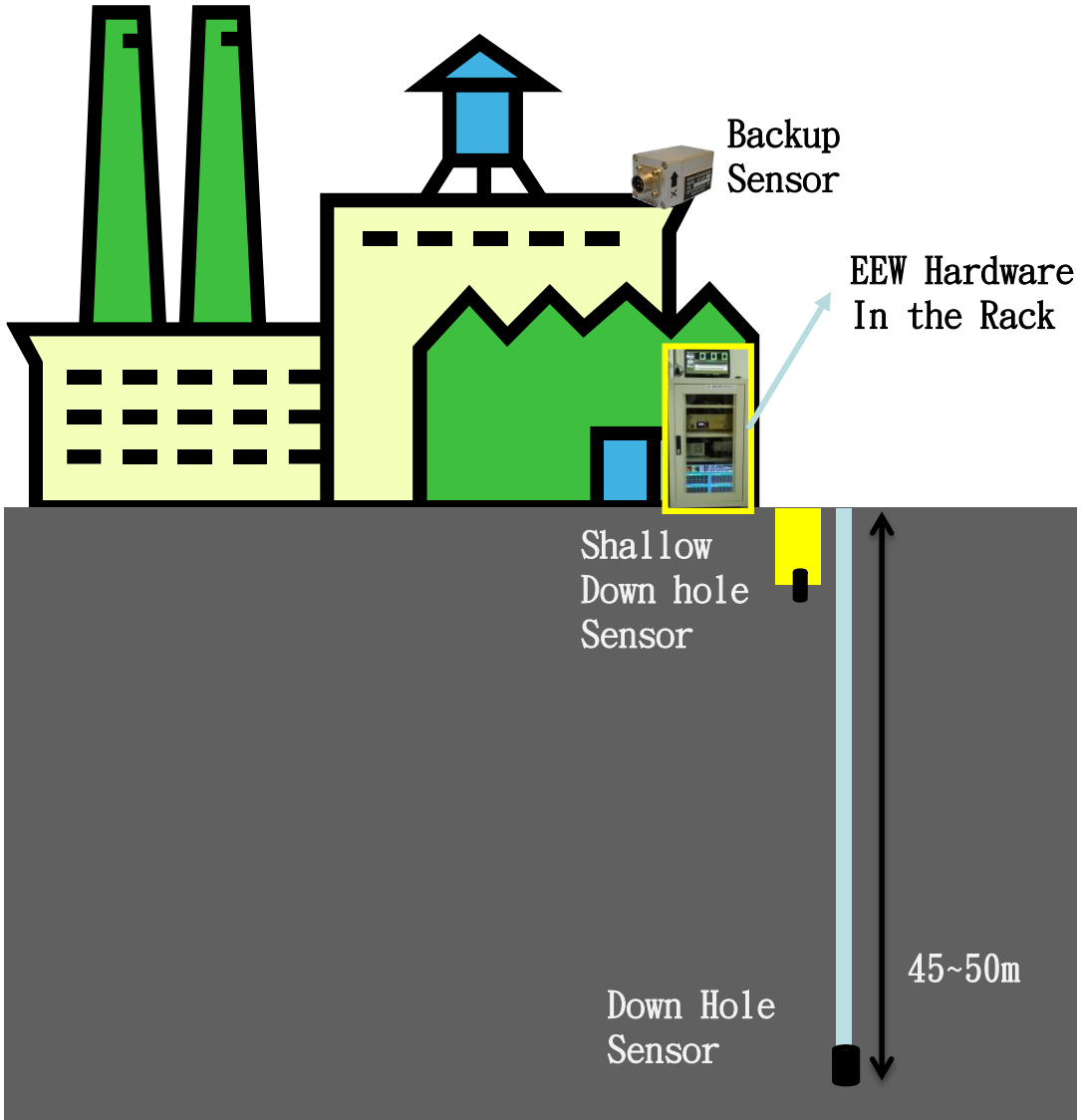
EEWS Station Name	Warning Time(sec)	Predicted Intensity	Measured Intensity	Predicted PGA	Measured PGA	Remark
東和國小	23.96	3	3	16.43	9.20	SVM ver2
斗六	24.05	4	3	27.78	10.08	Tc
雲林	27.19	2	2	3.18	5.09	SVM ver1
港坪國小	5.16	4	2	27.26	4.47	Tc
育人國小	26.26	4	2	30.63	6.66	Tc
宜蘭國小	18.15	5	4	157.87	42.21	Tc
南安國中	17.70	4	4	31.57	39.67	SVM ver1
光復國小	15.82	3	2	19.35	6.32	Tc
玉東國中	18.71	4	2	54.91	7.78	Tc

EEWS Station Accurate Rate on Last Year

Station Name	Date	Accurate Rate	Number of Times(Per Month) Trigger Event	Method
宜蘭國小	2014.07.01 | 2015.06.30	61.17% 928/1517	126.4	τ c
港坪國小	2015.01.18 | 2015.06.30	60.00% 6/10	1.8	τ c
南安國中	2014.07.01 | 2015.06.30	98.04% 5592/5704	457.4	SVM ver1
光復國小	2014.07.01 | 2015.06.30	88.10% 148/168	20.8	τ c
玉東國中	2014.07.01 | 2015.06.30	91.98% 757/823	68.6	τ c
育人國小	2014.07.01 | 2015.06.30	77.09% 138/179	14.9	τ c
新興國小	2015.01.10 | 2015.06.30	97.95% 239/244	43.3	SVM ver1
東和國小	2015.01.23 | 2015.06.30	85.78% 199/232	40.2	SVM ver2

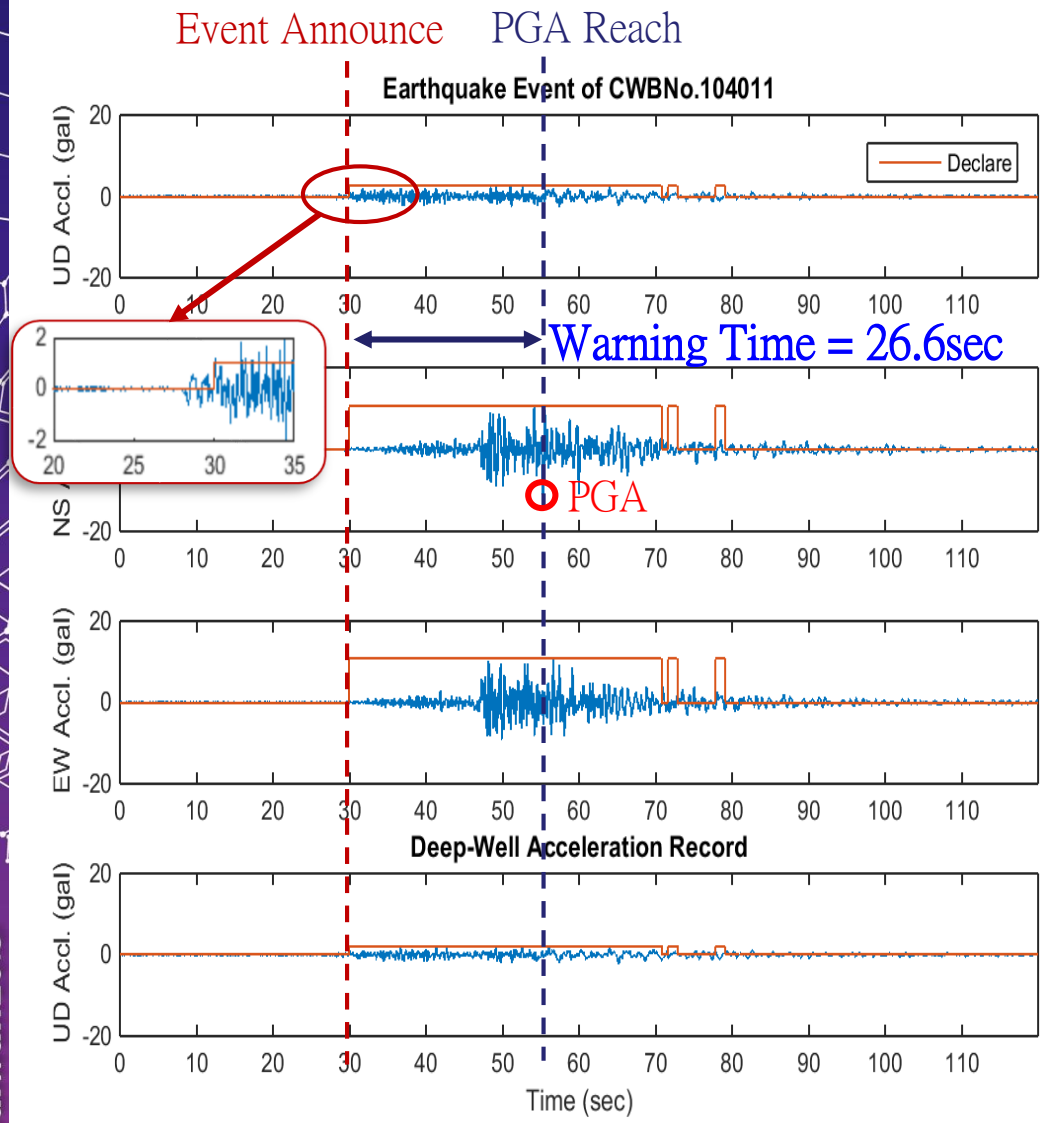
EEWS for High-Tec Plant

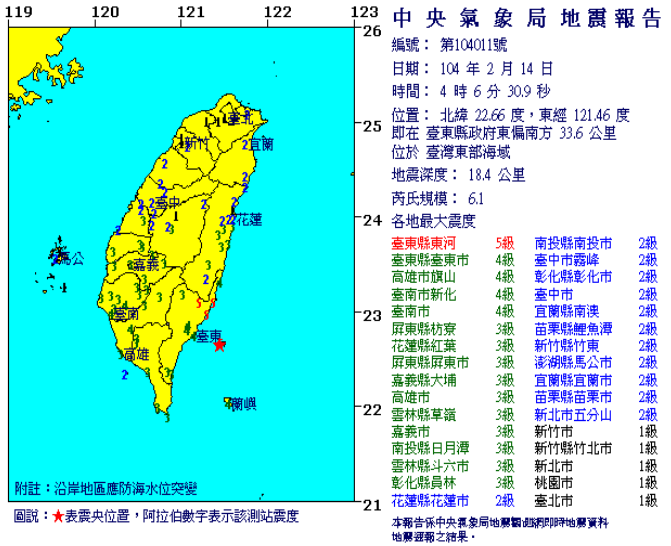
On-Site EEWS for High-Tech Plant



- EEW Hardware Equipped in the Cabinet
- Down Hole Sensor + Shallow Down Hole Sensor + Backup Sensor: Reduce False Alarm
- Annually EEW Report
- Customized EEW

Real Performance in EQ. 104011





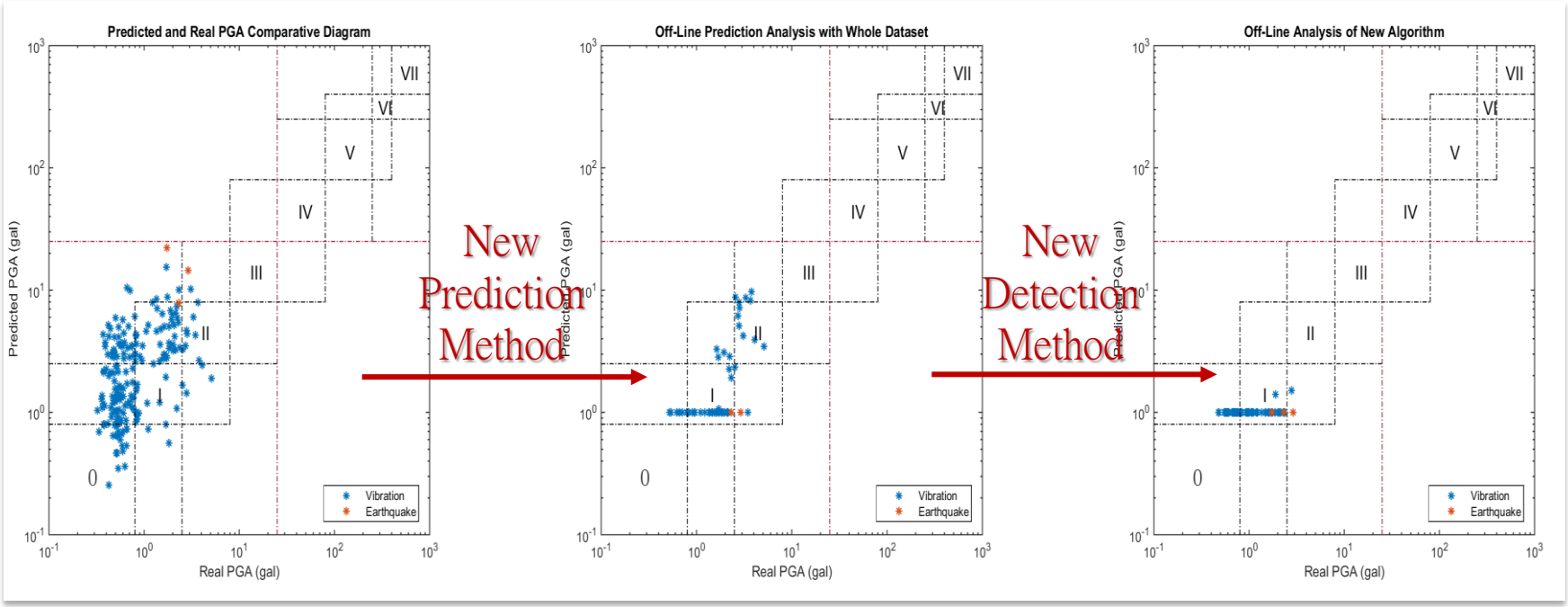
- Announce Time: 04:06:55
- Warning Time: 26.6 sec
- Epicenter Distance: ≈130 km

Performance	Real	On site
Intensity	3	3
PGA	11.9	11.8

New Approach of On-site EEWS

More Customized

Online Status | New Solution | Future Work



- Accuracy Rate: 81.8%

- Accuracy Rate becomes 100%

- Accuracy Rate keeps 100%
- The non-earthquake events are highly eliminated.

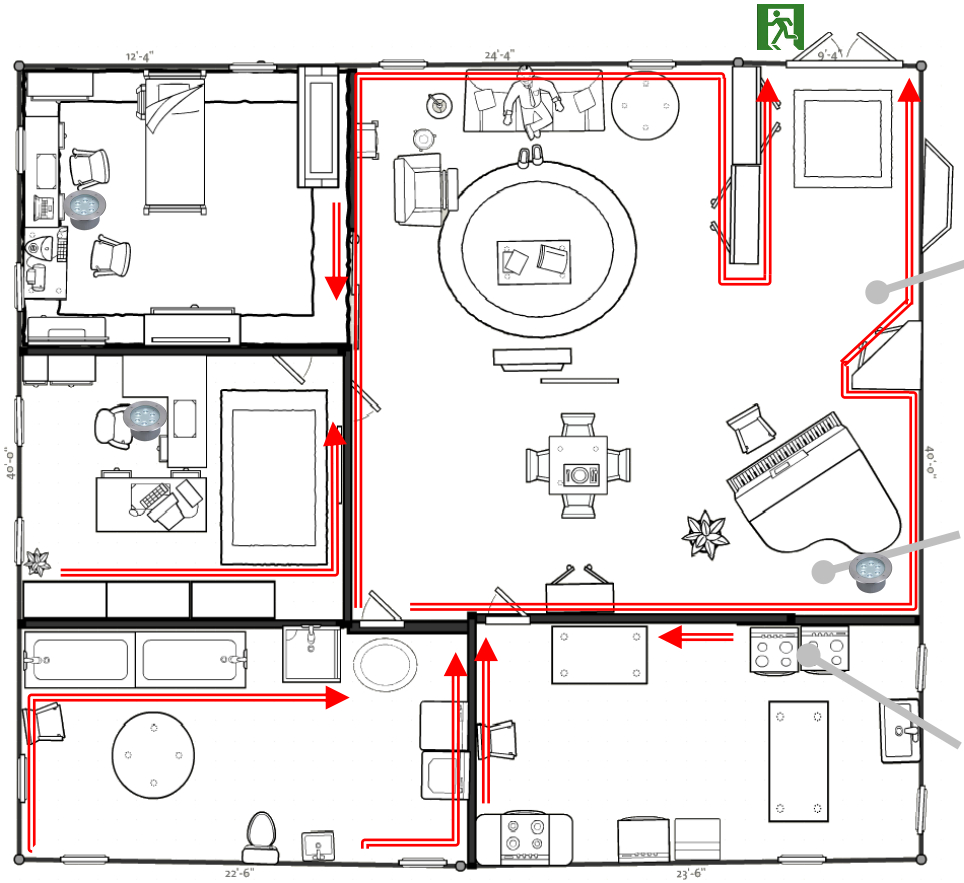
Application of EEWS

At Home – when earthquake is coming…

Electric bulletin board will show the evacuate icon

Elevator will stop at the closest floor and open the door.

The door will open automatically.

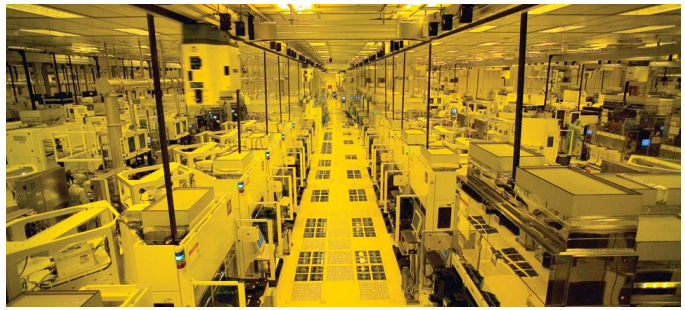


Emergency exit light wi
open to give direction.

The LED light will provide spot light to the safety zone for shelter.

Gas will be closed automatically.

In Plant – when earthquake is coming…




Think

15s, there's lots of thing we can do to save money.



EEW broadcast, waning light, LED Display, SMS message will help people to take shelter. Also, the digital signal will be sent to EOC or the automatic production control system to proceed the emergency operation procedur

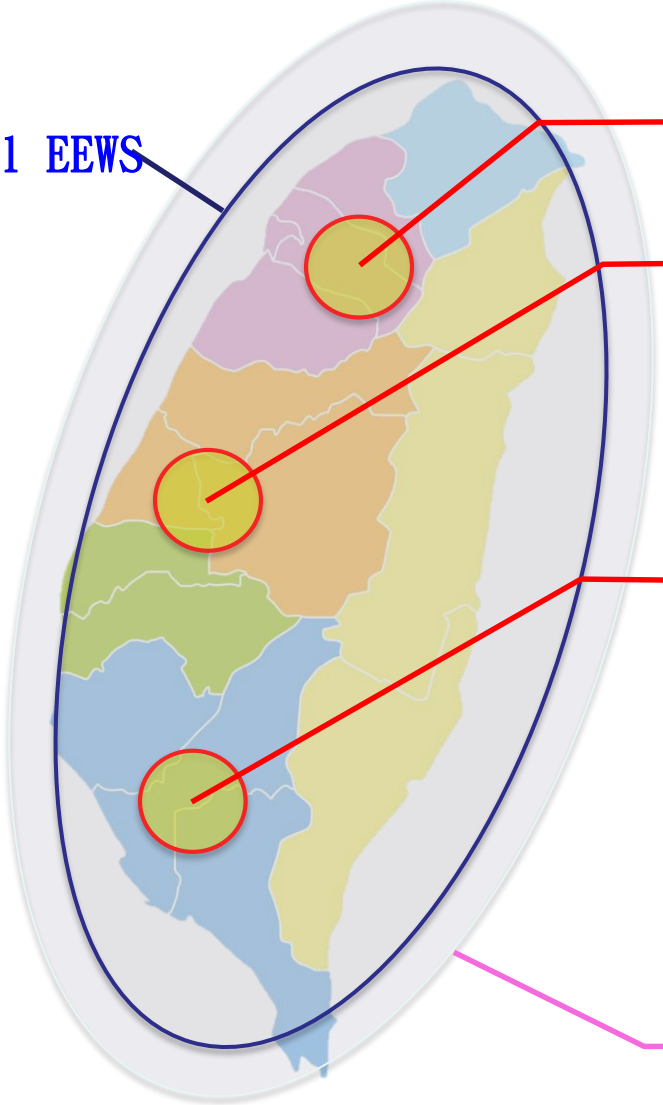

Speaker

SMS

Others Devices (Dry Contact, RS485, etc.)

There’s more

Integrated Earthquake Early Warning System for Science Park



NCREE Regional EEWS

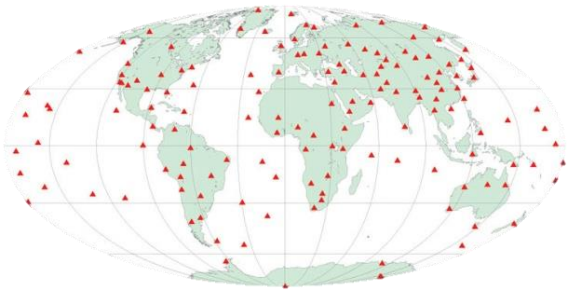
NCREE On-site EEWS at Hsinchu

NCREE On-site EEWS at Taichung

Warning time / Epicenter distance
~15s / ~60km
~20s / ~100km

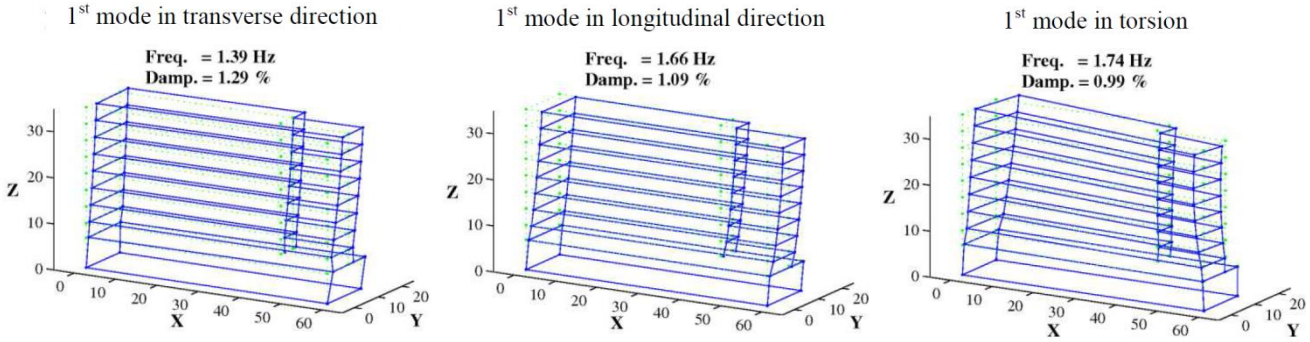
NCREE On-site EEWS at Tainan

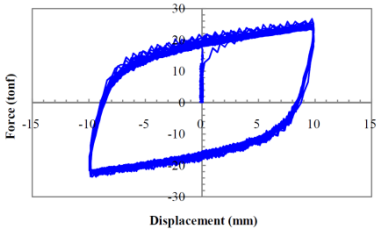
Global Seismograph Network

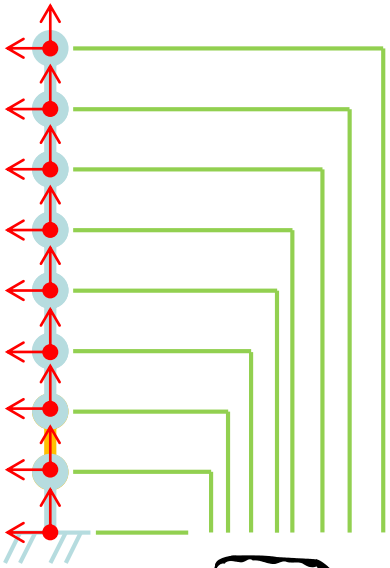


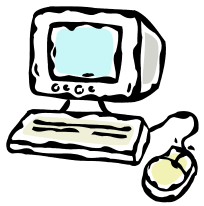
CWB Regional EEWS

Structural Health Monitoring System

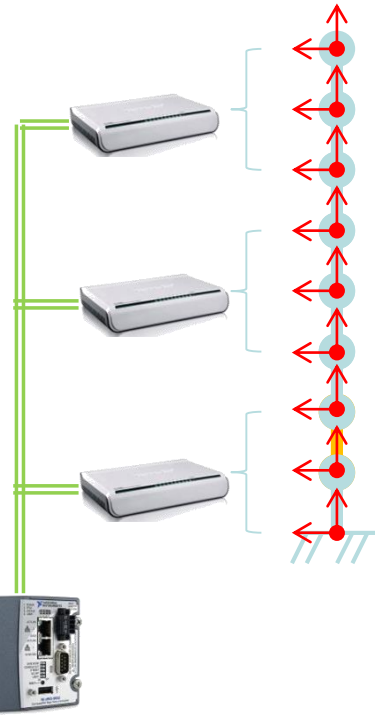






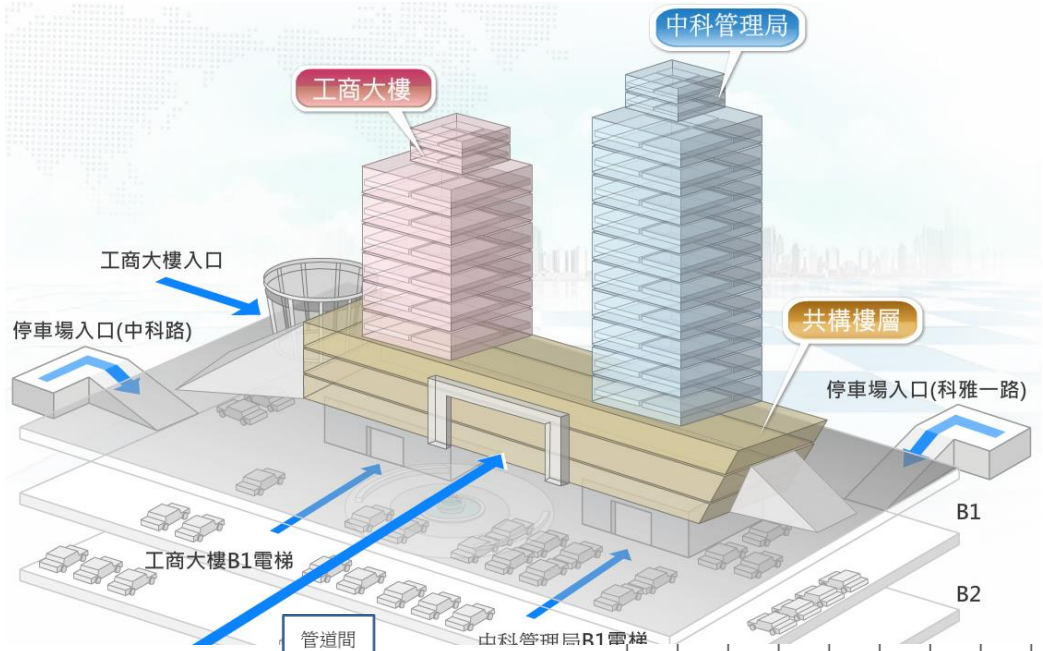


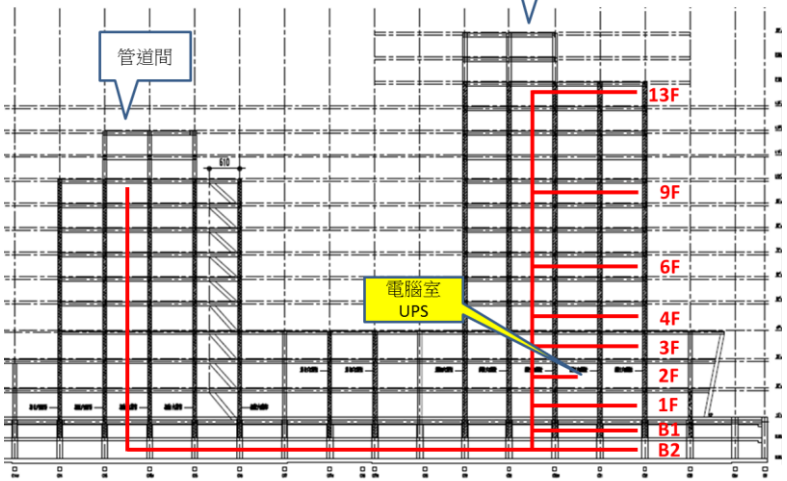
Traditional	SSHMS
Centralized sampling	Decentralized sampling
Wired, analog	Multiple communications
w/o embedded calculation	Online SHM calculation

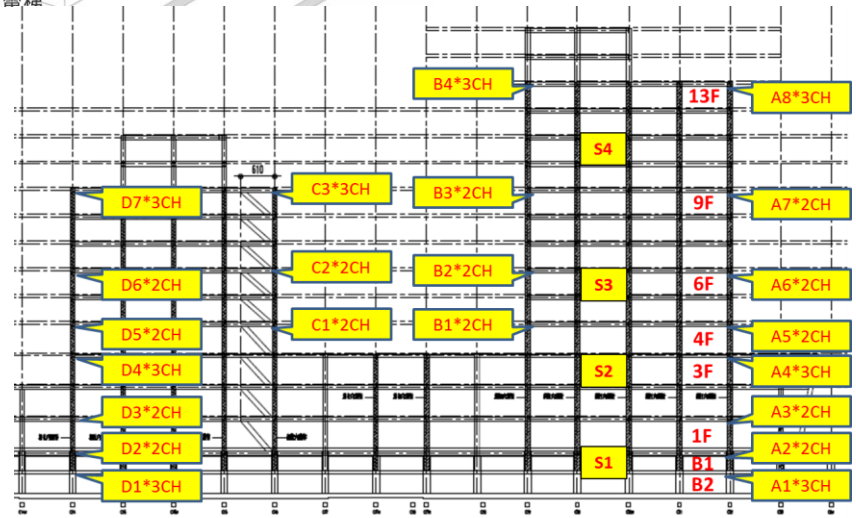


Structural Health Monitoring System

Office Building of Central Taiwan Science Park







Total Solution of Seismic Disaster Prevention

Combined the EEW and Structural Health Monitoring

Hardware

- EEWS
- SHM
- Automation

Office building

Software

- DP Program
- DP Drill
- DP Service

Hi-Tec plant

THANKS

The Total Solution of
Seismic Disaster Prevention
will get ready soon