

## Practical Application of Site-specific Earthquake Early Warning (EEW) System

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## Objectives of research

- 1 To improve estimation method of JMA seismic intensity of earthquake early warning (EEW) information based on site-specific data
- 2 To develop on-site warning (OSW) system to improve timing of warning and reduce the false alarms
- 3 To develop application to practical use in construction company
- 4 To develop integrated system to apply to system shutdown

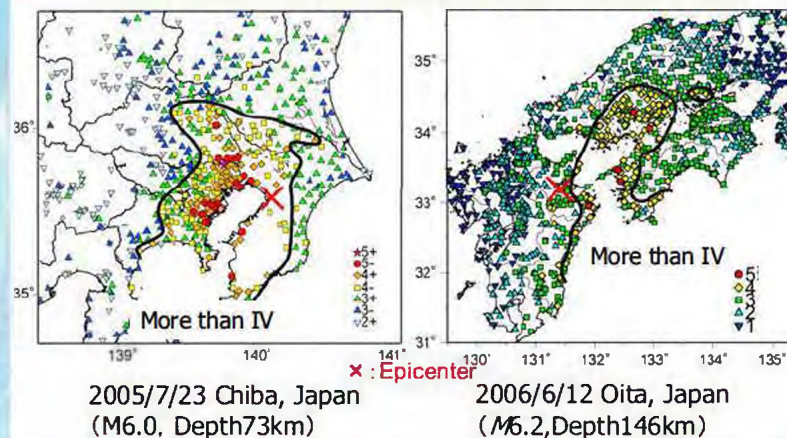
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## Improvement of JMA Seismic Intensity Estimation for EEW

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## JMA seismic intensity is not always reduced in a concentric fashion



Seismic intensity distribution can't be precisely explained using attenuation relationship.

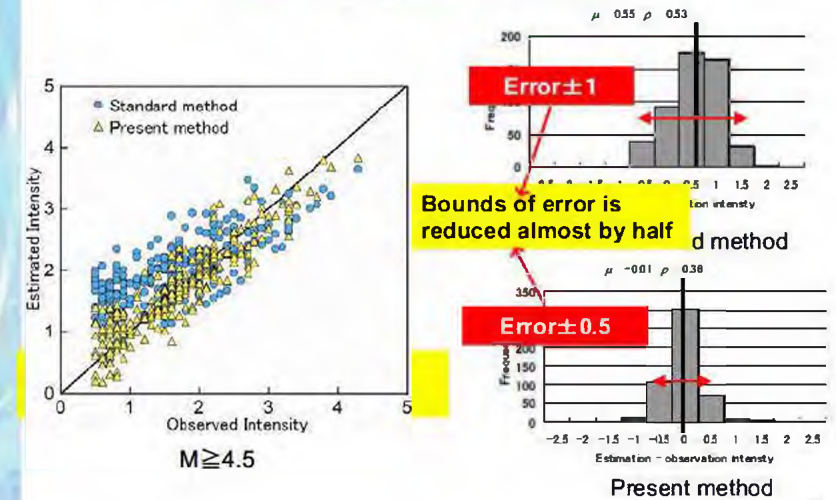
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## Improvement of seismic intensity estimation

- Standard method: Attenuation relationship + soil amplification factor
- ↓
- Analysis based on seismic intensity database including recent and historical earthquakes
- Considering source, path and local site effects
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- Original attenuation relationship for each site + epicenter, depth correction factors

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## Comparison of accuracy (Tokyo, 1997-2007)



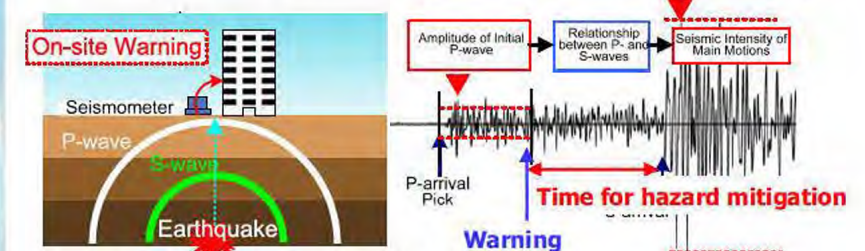
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## Development of On-site Warning(OSW)

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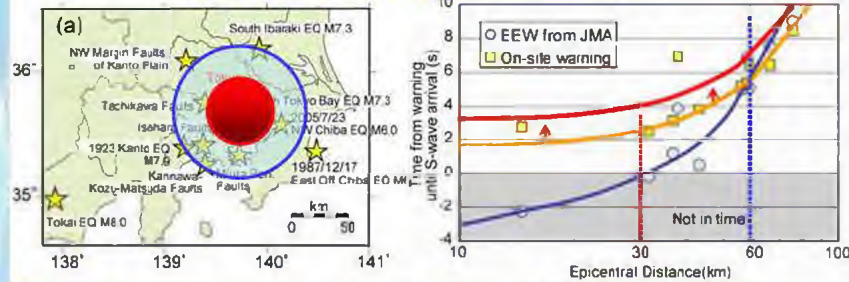
## Concept of P-wave On-site Warning(OSW)



- P-wave pick-up sensors are installed on the soil surface at a site or on the basement of a building.
- The warning can be issued before S-wave arrival taking advantage of the difference between the velocities of P and S waves.
- The intensity estimation method is based on the empirical amplitude relationship between P and S waves.

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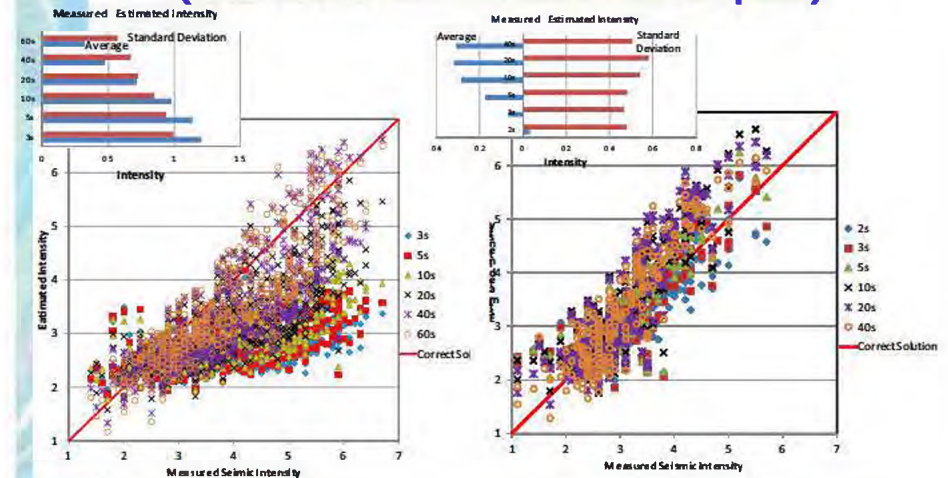
# Comparison of time for seismic hazard mitigation



- The on-site warning is faster than EEW from JMA for earthquakes within about 60km epicentral distance.
- In particular, within about 30km, the EEW information may not be transmitted before S-wave arrival.
- If deep borehole data is available in real-time, on-site warning is more effective.

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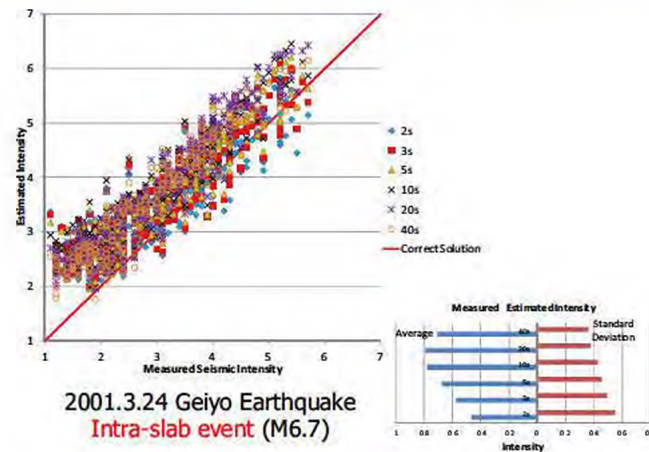
# JMA seismic intensity estimation for OSW (Estimation time after P-wave pick)



2011.3.11 Tohoku Earthquake  
Plate boundary event (M9.0)

2008.6.14 Iwate-Miyagi Earthquake  
Inland shallow event (M7.2) 10  
K-NET observation data

# JMA seismic intensity estimation for OSW (Estimation time after P-wave pick)



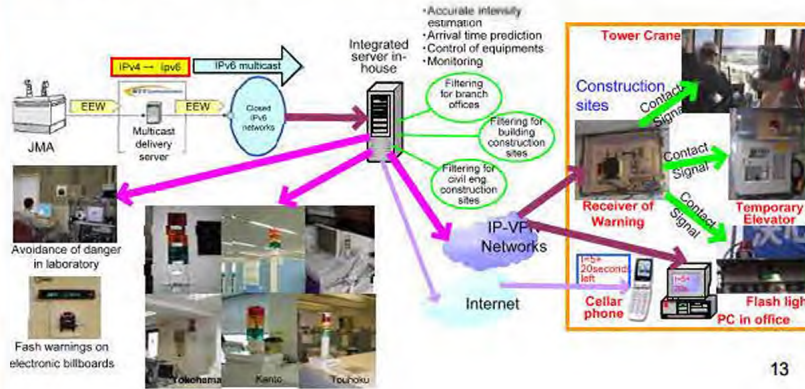
2001.3.24 Geiyo Earthquake  
Intra-slab event (M6.7)

K-NET observation data 11

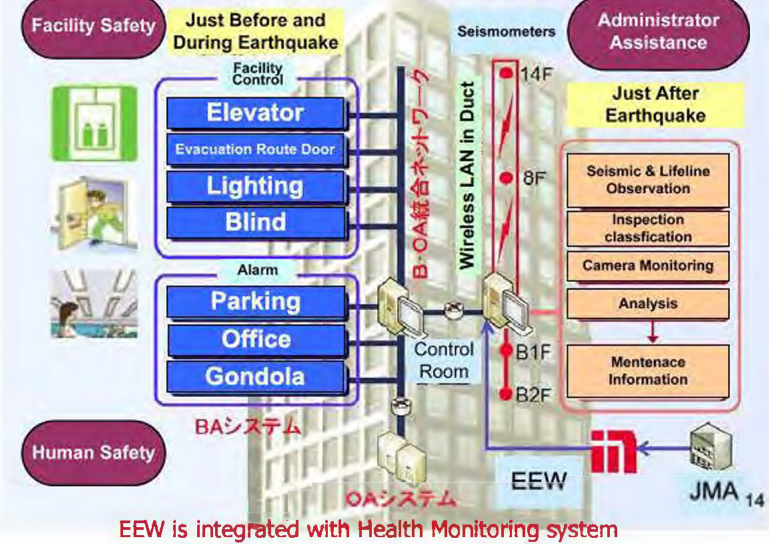
## 3 Application in Construction Company

# System configuration of EEW

- Integrated server can intensively receive and process EEW information from JMA and can extensively deliver it to a whole construction company.
- EEW information can be transmitted through company networks to headquarters, branch offices and construction sites for about 1 second.



# Integrated system in headquarter office



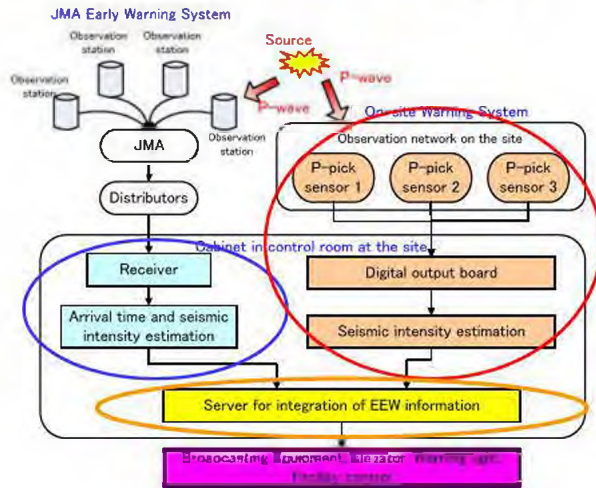
# Ceiling alarm lamps in offices



# Other displays and alarm lights

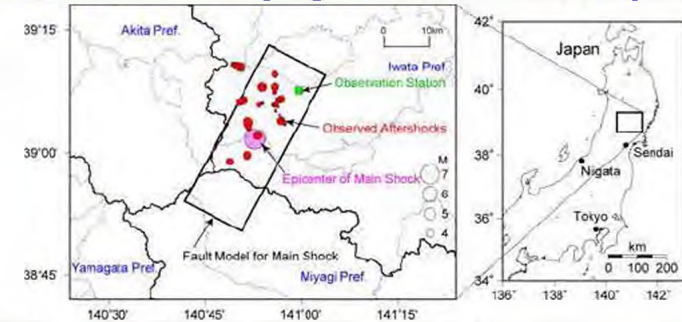


# Combination system of EEW from JMA and OSW



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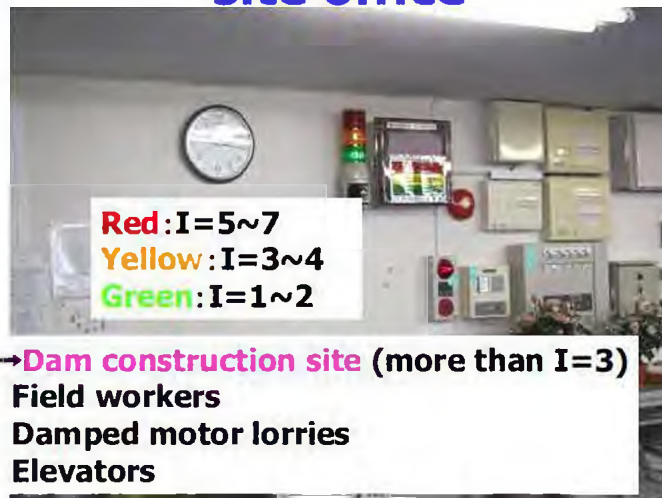
# Example in construction site Measures against aftershocks of the 2008 Iwate-Miyagi Inland Earthquake



- EEW from JMA which had been operating since 2007 was output to the site after the arrival of the S-wave in the main shock.
- Since the aftershocks were quite active, we installed the on-site warning system and modified EEW to integrated warning system.

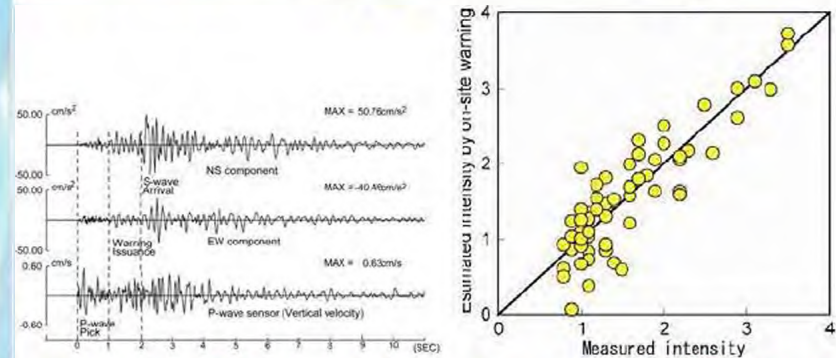
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# Alarm devices in construction site office



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# Results of OSW against aftershocks of 2008 Iwate-Miyagi inland earthquake



Example of time series observed on July 14, 2008

Accuracy of JMA seismic intensity estimation (July – September, 2008)

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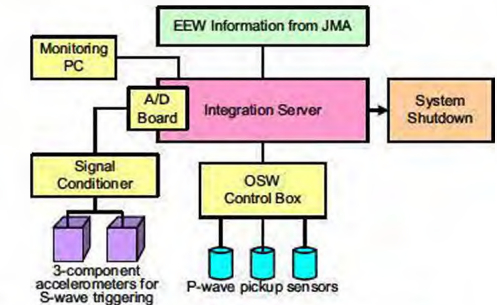
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## Integrated EEW System for Shutdown of High-Reliability System

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## Robust and reliable integrated EEW system for system shutdown

- The OSW by itself is used only for near-field earthquakes.
- The EEW from JMA combined with OSW is for the others.
- In case of underestimation by the OSW and EEW from JMA, accelerometer installed on the target floor in a building is used as S-wave triggering.



For critical facilities such as precision machine and semiconductor factories

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## Combination of EEW from JMA and OSW using Bayesian estimation

- JMA intensity  $I_E$  is estimated by average of EEW and OSW weighted using their lognormal standard deviations and corrected by offset of mean value.

$$I_E = \frac{\beta_{AO}^2}{\beta_{AJ}^2 + \beta_{AO}^2} (I_J + \bar{\gamma}_J) + \frac{\beta_{AJ}^2}{\beta_{AJ}^2 + \beta_{AO}^2} (I_O + \bar{\gamma}_O)$$

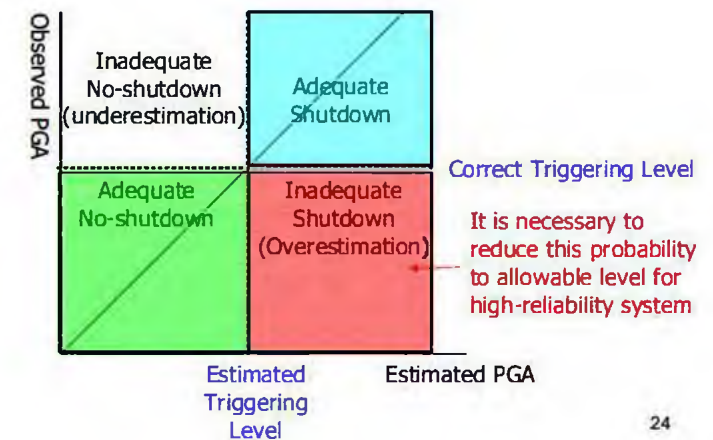
$$I_E = 0.3I_J + 0.7I_O + 0.4$$

Time after P-wave Pick (s)	Time of 2011/3/11	M	EEW from JMA		OSW		Combination	
			Estimated Intensity $I_J$	Estimated Intensity $I_O$	Estimated Intensity $I_E$	Estimated peak ground acceleration (Gal)		
0	14:47:38	7.7	3.1					
3	14:47:41	7.7	3.1	2.9	3.4	22		
5	14:47:43	7.7	3.1	3.0	3.4	24		
10	14:47:48	7.9	3.3	3.0	3.5	26		
20	14:47:58	7.9	3.3	3.2	3.6	29		
40	14:48:18	8	3.5	3.4	3.8	36		
60	14:48:38	8.1	3.6	3.5	3.9	41		
Measured Intensity							3.6	
Measured peak ground acceleration								54

Example at K-NET Shinjuku (TKY008), Tokyo at the Tohoku earthquake

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## Idea of adequate system shutdown Using EEW from JMA and OSW



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**Thank for attention!**