MEMS acceleration sensors of automotive for Infrastructure Management

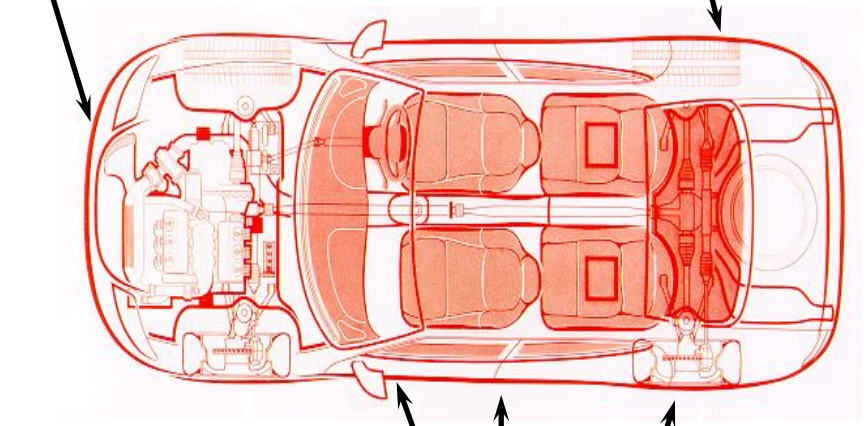
April 21, 2015

Akebono Brake Industry Co., Ltd.
Sensor Solutions Department
Takashi Kunimi

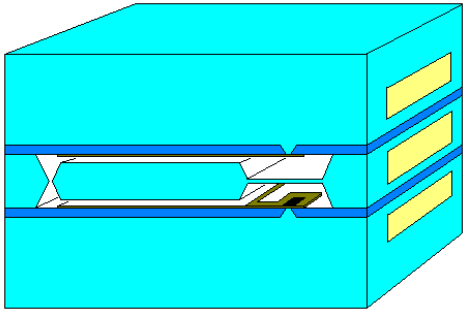
Contents

1) MEMS sensors for automobiles

Purpose (about 20 accelerometers built-in)



Accelerometer
9x5x11mm 1g



Sensor element

1-1) MEMS sensors for automobiles

Characteristics of MEMS accelerometer for automobiles

High performance

High grade vehicle chassis control technology using accelerometers or angular rate sensors has been developed (Electronic stability control etc.)

High reliability

No malfunctions (accomplishments for ABS, airbag etc.)

High durability

Essentially no maintenance for automobile sensors.

Low costs

2) Measurements by silicon MEMS sensors

*Vibration measurement (DC～250Hz)

Vibration level detection ----- Seismometer, Railroad Car Behavior Detection

Resonance frequency change ----- Constructions, building deterioration

Acceleration, distance detection ----- Power line position measurement

*Inclination measurement (stability of 0.001deg/day)

Angle of inclination ----- Underground/Ground inclinometer

----- Collapse prediction

----- Measurement of inclination of structures

3) Japans landslide disasters

Situation of designated landslide disaster hazard areas

Earth & rock avalanches	Steep slopes	Landslides	Sum
125,545 (places)	225,495	5,340	356,380

Landslide disasters

Places:	2014 Hiroshima	2013 Izu Oshima	2011 Wakayama
Missing and/ or dead persons	74	40	55

2014 Hiroshima

2013 Izu Oshima

2011 Wakayama

Data & Pictures: Ministry of Land, Infrastructure, Transport and Tourism, NPO Sediment Disaster Prevention Publicity Center (PBC)

4) Detection of collapses

Detection of collapses: Examples of usage at infrastructure maintenance

Slope collapse detection
(steep slopes, landslides)

Aim

Provide a slope collapse detection sensor, usable as a simple surveillance network with aim of efficiency for a wide area control in slope disaster prevention.

With the traits of small size and low price a wide scope (area) surveillance is possible

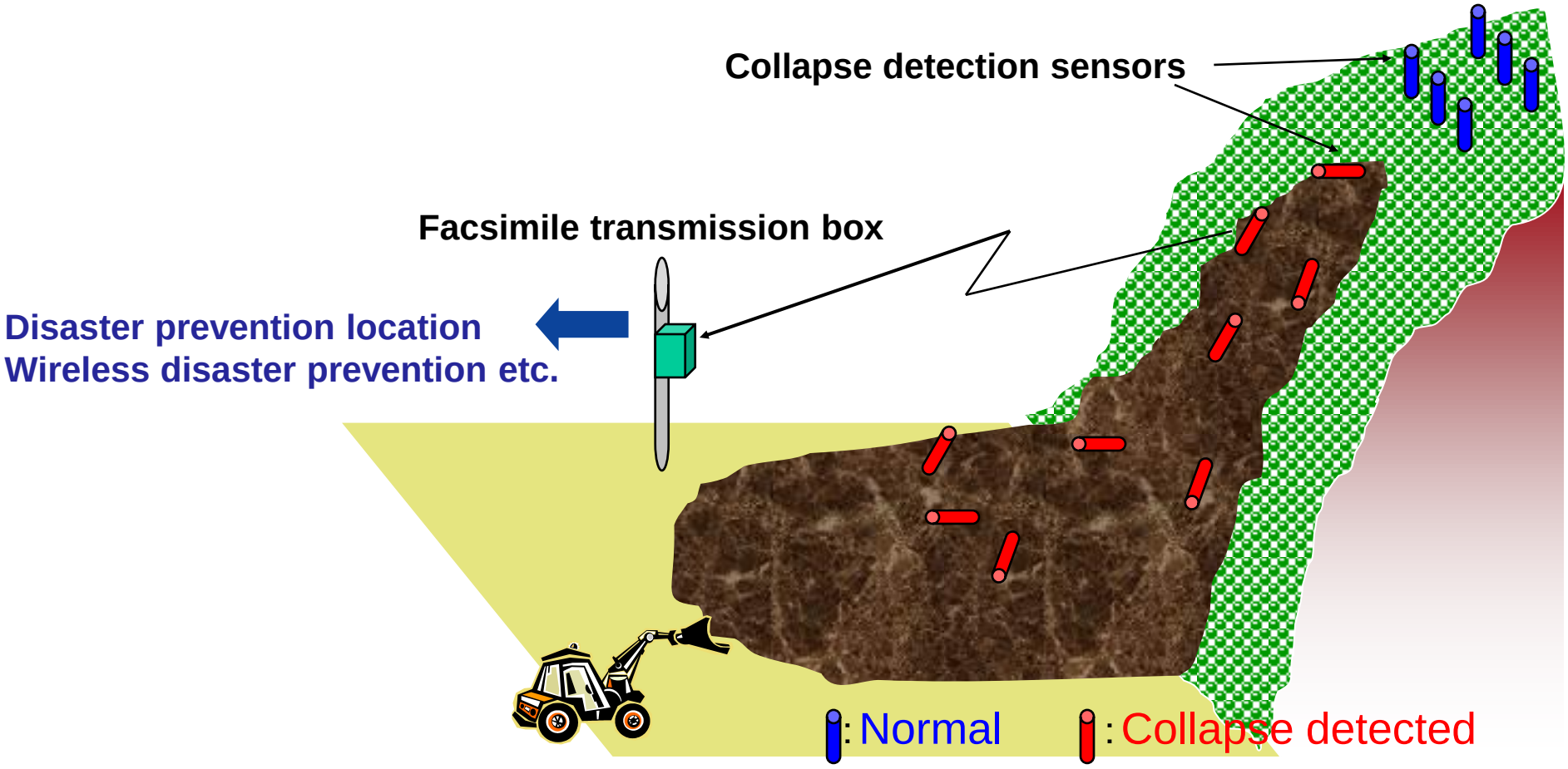
4-1) Detection of collapses

Disaster prevention priority	Subject	Role of information flow management	Demanded facts
Rank 1	**Disaster prevention locations** Public offices, police stations, fire stations, shelters/places of refuge	Earthquake resistance reinforcement, taking countermeasures beforehand by disaster prevention construction work	
Rank 2	**Control observation points** Sites, where beforehand harm prevention is demanded	Observation of the time frame until countermeasures by monitoring, we want to know the presage	Stable real-time observation over a long period
Rank 3	**Phenomenon observation points** Sites, where harm can be reduced due to a faster understanding of the occurrence of natural phenomena	We want to know very fast, whether a disaster phenomenon occurred or not	Transmission after occurrence of phenomenon Usage for long period Without electrical power Control unnecessary Low cost
Rank 4	**Semi-observation points** Rehabilitation by countermeasures taken after the happening	Regular patrol, visual inspection, sites with possibility of rehabilitation after the happening	

4-2) Detection of collapses

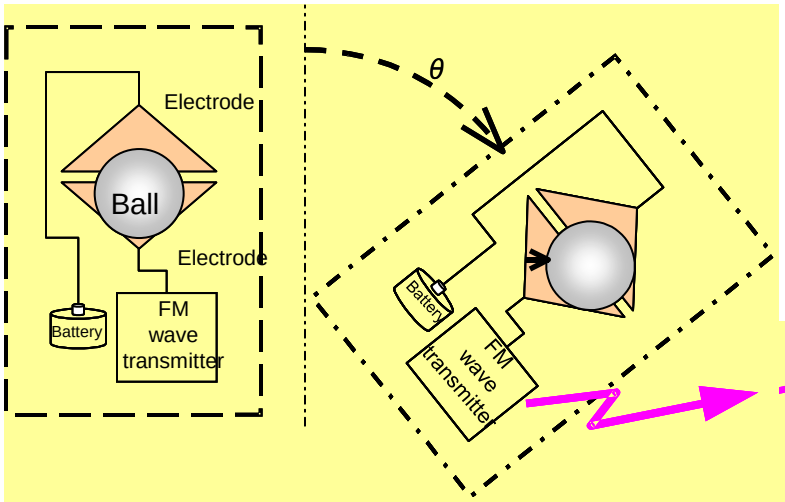
System Overview

Rank 3 System for phenomenon observation



4-2) Detection of collapses

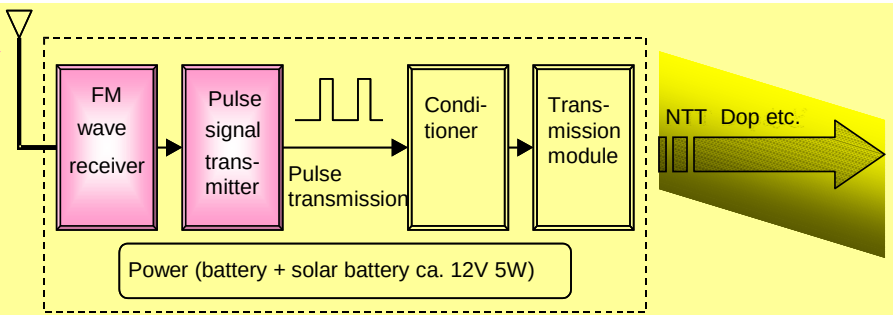
Rank 3　System for phenomenon observation

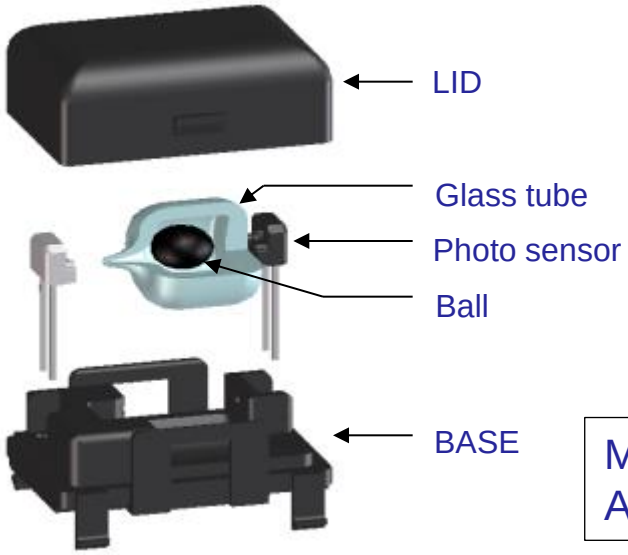


Collapse detection sensors (send)

Used for automotive keyless entry system

Facsimile transmission box (send)





Motorbike overturning sensor:
At motorbike overturn the engine will be stopped by the sensor

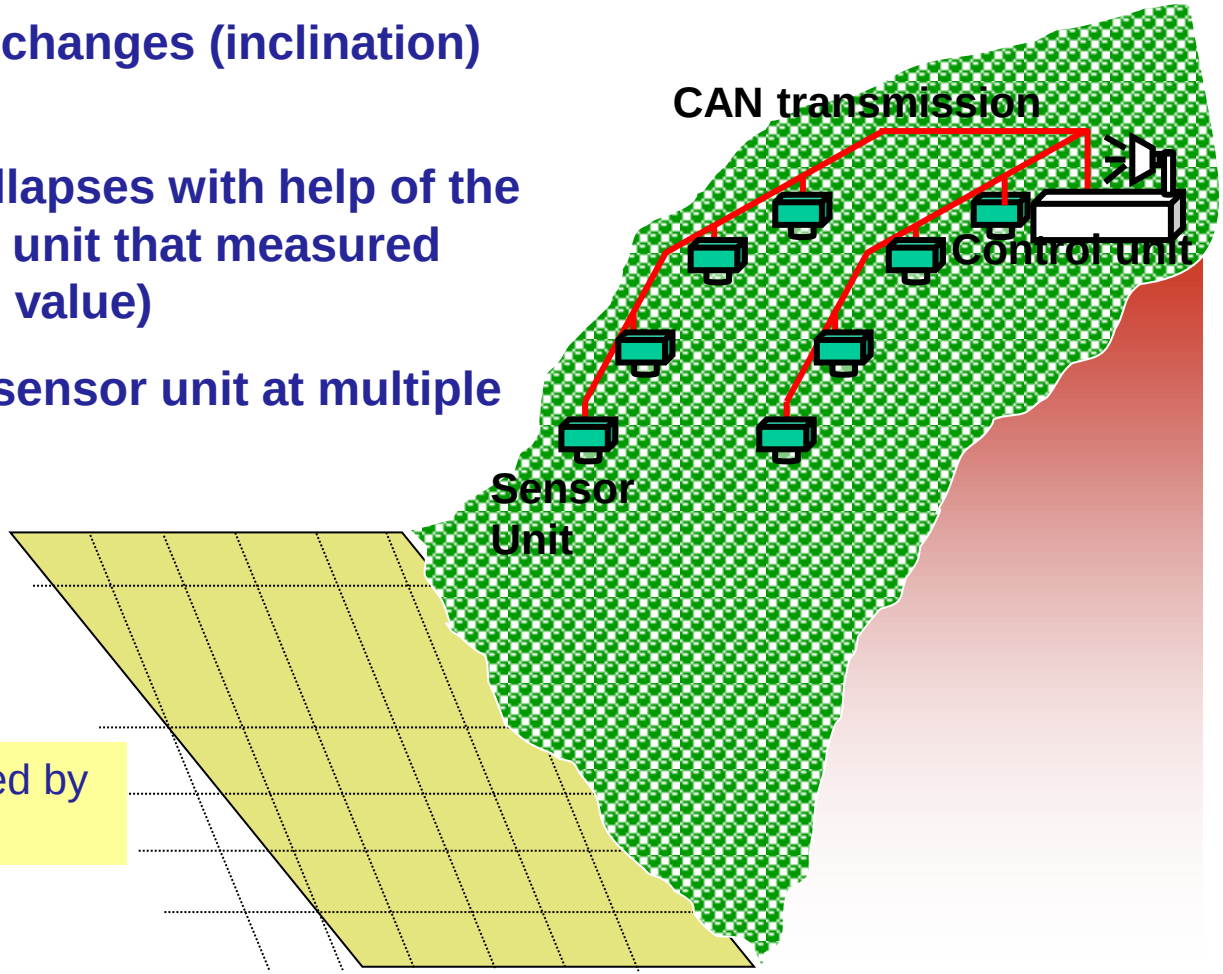
4-3) Detection of collapses

Rank 2 System for control observation

(1) Measurement of ground changes (inclination) with the sensor unit

(2) Detect signs of slope collapses with help of the inclination of the sensor unit that measured changes above the fixed value)

(3) Possibility to install the sensor unit at multiple locations

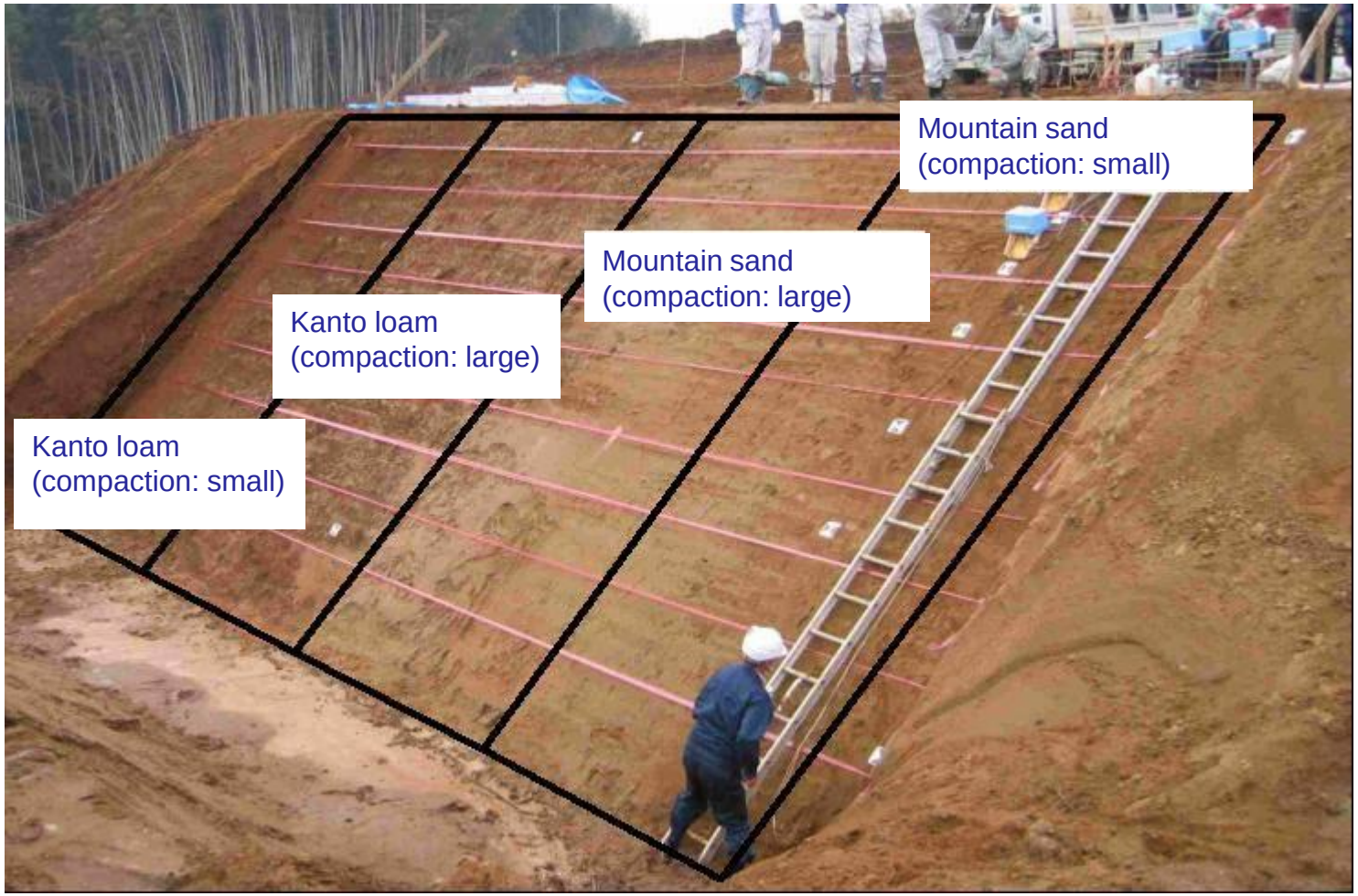


The inclination will be detected by a MEMS accelerometers

4-3) Detection of collapses

System test overview

Test embankment (slope inclination 45 degree)



Quoted literature: Kazuya Ito, Yasuo Toyosawa: Actual size slope collapse experiment related to slope instability due to excavation of the lower slope part, Civil engineering scientific society collected works C, Vol. 65, No. 1, pp. 254-265, 2009.

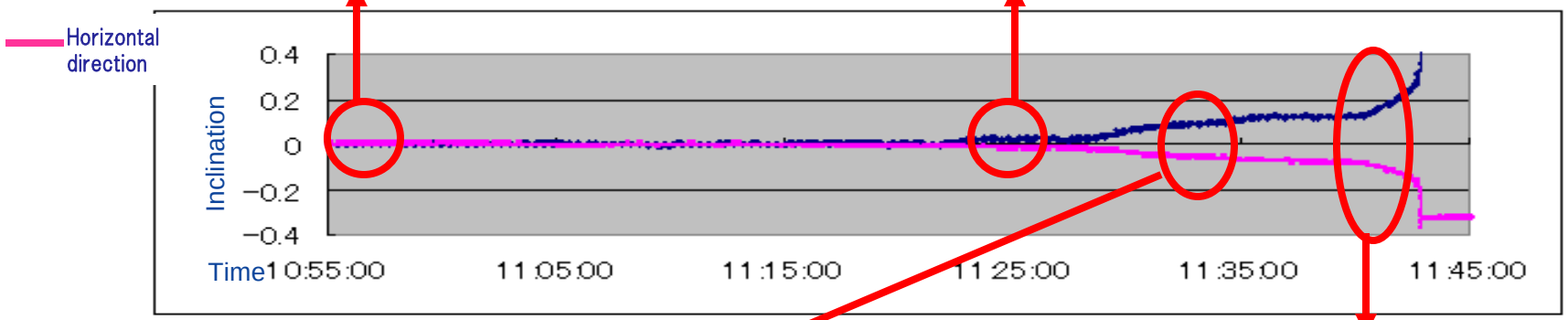
4-3) Detection of collapses

System test result

Quoted literature: Kazuya Ito, Yasuo Toyosawa: Actual size slope collapse experiment related to slope instability due to excavation of the lower slope part, Civil engineering scientific society collected works C, Vol. 65, No. 1, pp. 254-265, 2009.

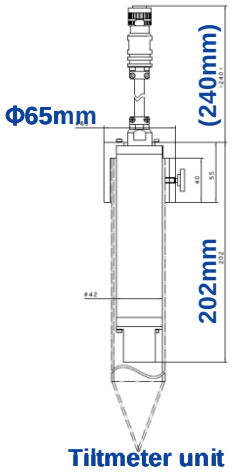
Excavation with a height interval of 0.5m

Data of sensor installed 0.5 m from top of slope



4-4) Detection of collapses

System



Tiltmeter unit

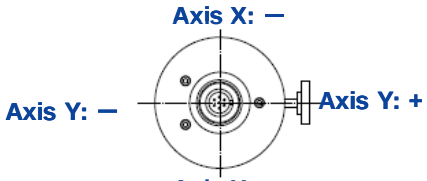
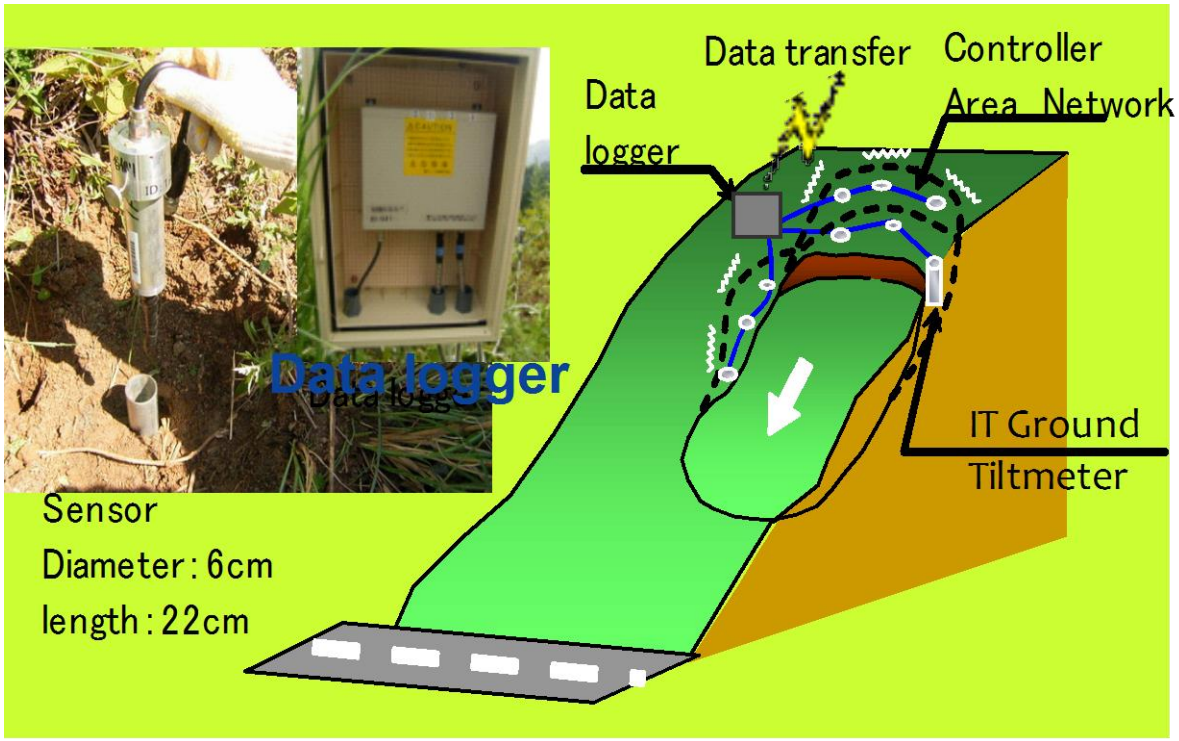


Figure: Axial ensitivity



Schematic view of landslide monitoring

Specifications:

- Number of the spindles: 2 axes（X,Y）
- Range of measurement: ±20deg
- Measurement accuracy: ±0.01deg
- Power supply: AC100V or DC12V

4-5) Detection of collapses

「IT Underground Inclinometer

and

「IT Ground Inclinometer」

This new system enables to measure several points automatically with MEMS accelerometers

Civil Engineering association technology development prize winning in 2003 fiscal year

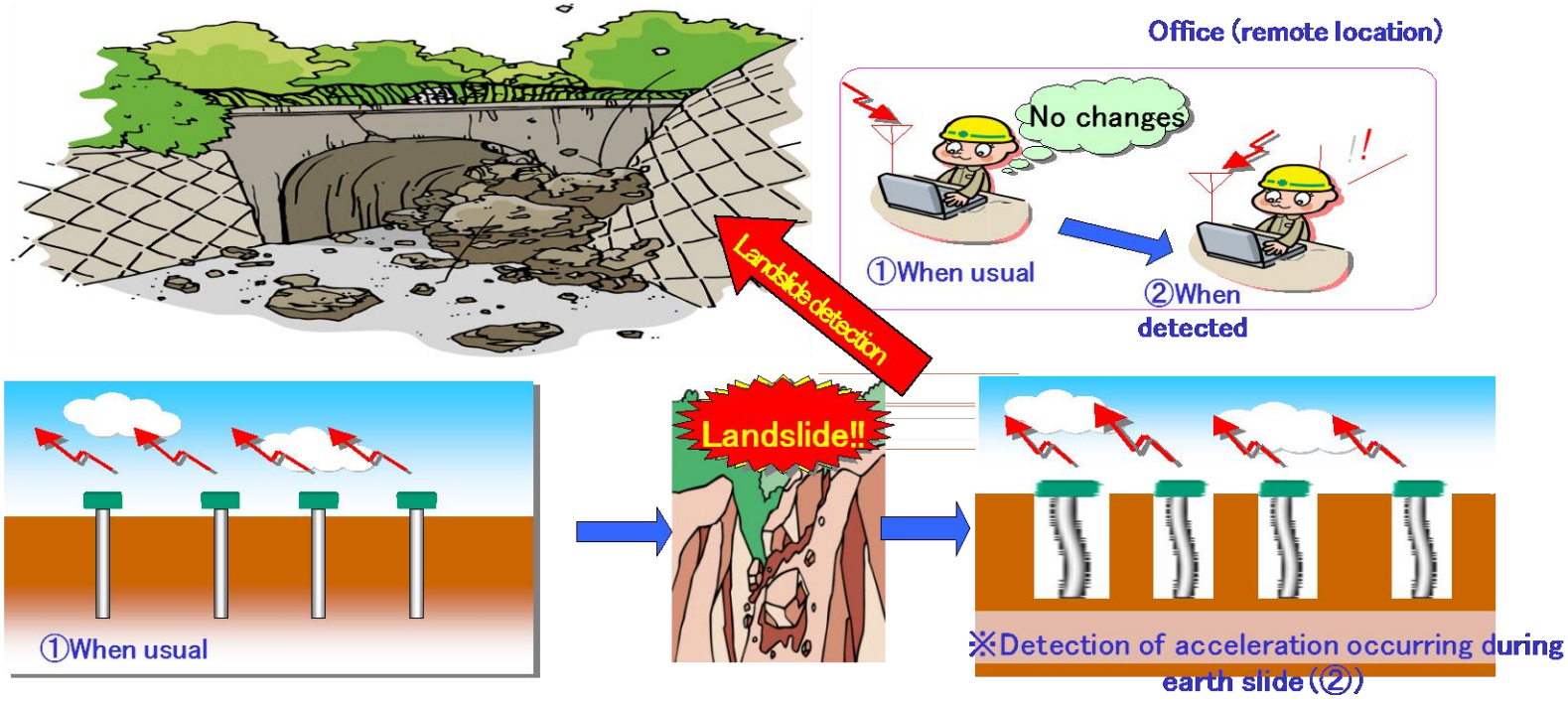
'Development of a ground inclination measurement system using accelerometers'

4-5) Detection of collapses

1. IT Inclinometer System（Landslide Monitoring System）

Concept of the system:

- Detect slight changes in the ground of slopes using acceleration sensors.
- Automatic measurement of many points.
- Easy to use & economically advantageous



（Jointly developed with Japan Highway Public Corporation）

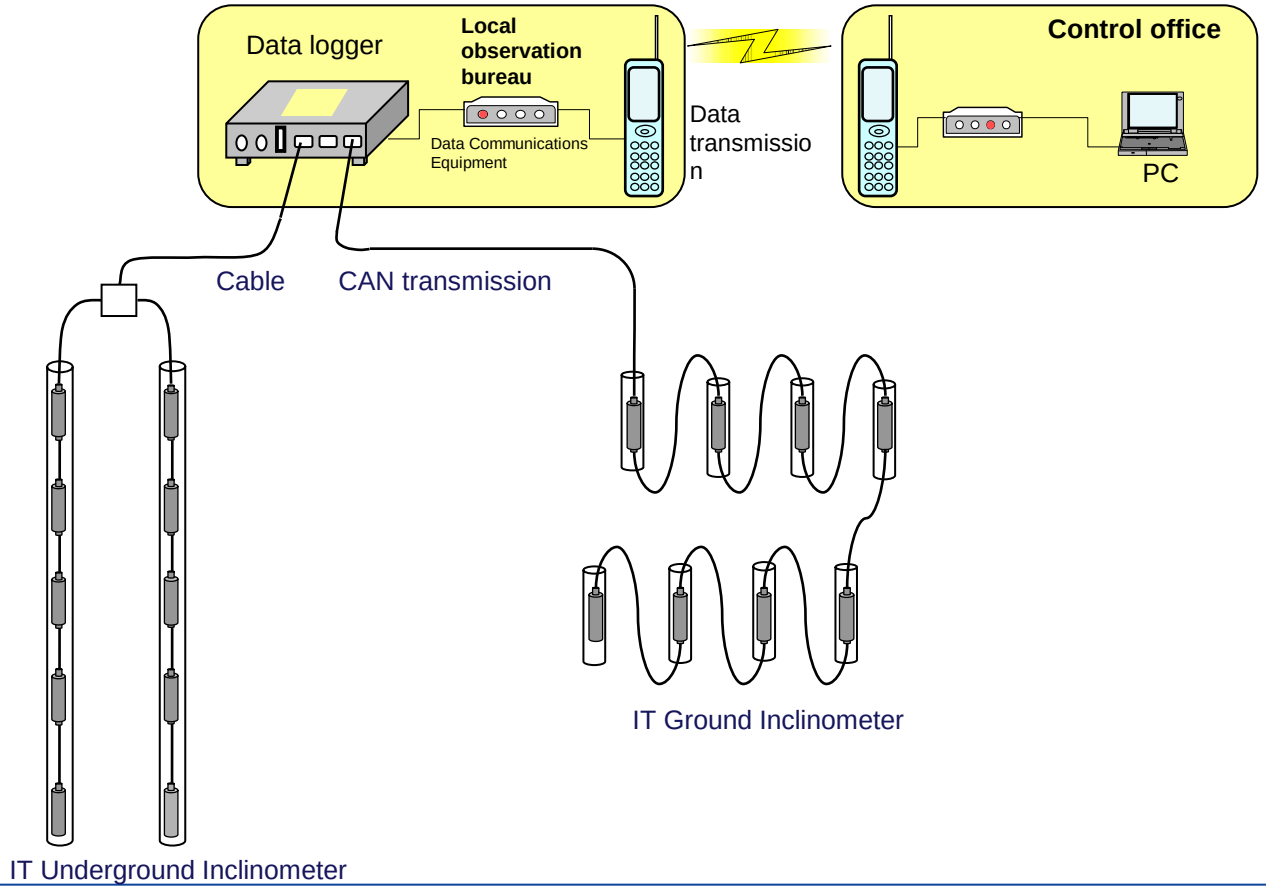
4-5) Detection of collapses

System

The IT Underground Inclinometer consists of measurement equipment and pipes. The IT Ground Inclinometer only consists of measurement equipment.

The data logger is connected to a PC, which collects the transferred data.

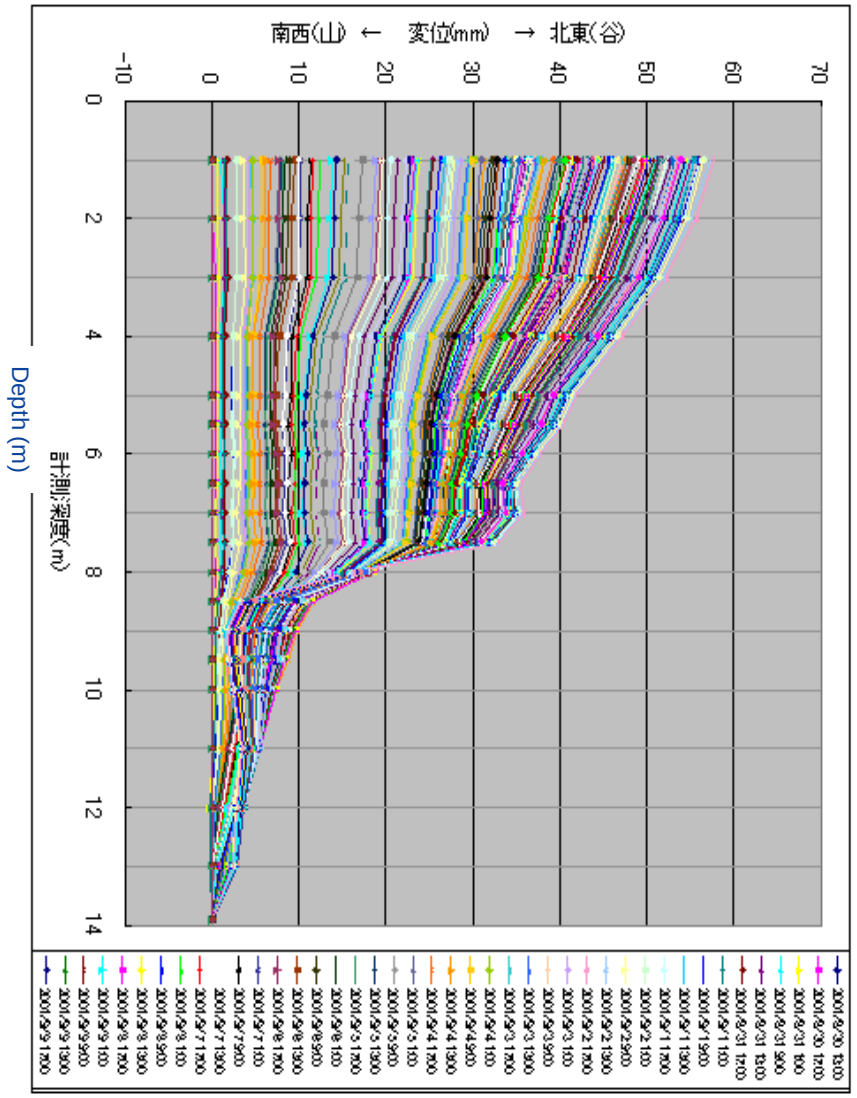
Collecting remote data by mobile phone is possible (optional)



4-5) Detection of collapses

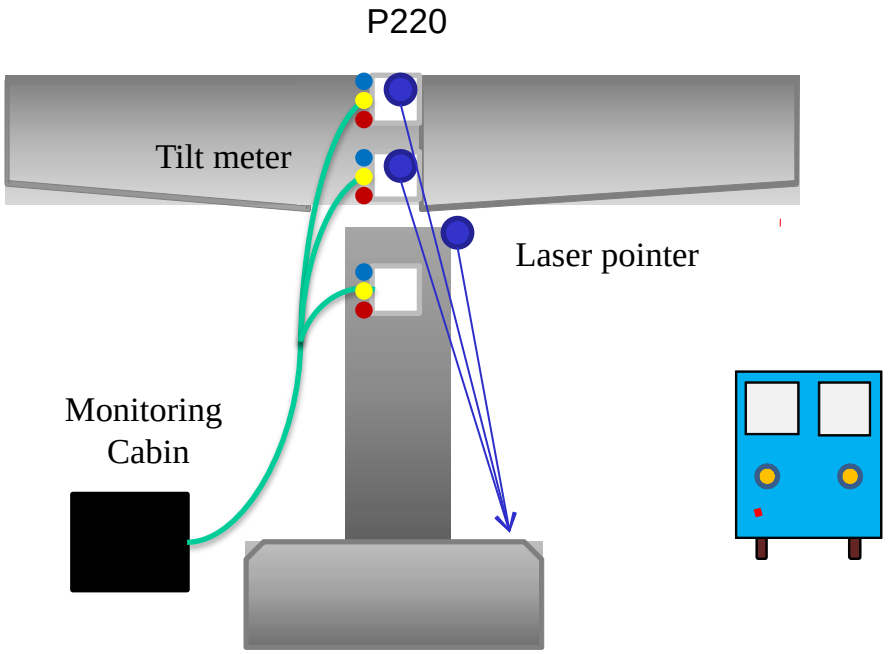
Actual survey data

Southwest (Mountain side) ← Displacement(mm) → Northeast (Valley side)



5) Monitoring bridge construction

Light Emitting Inclination Sensor



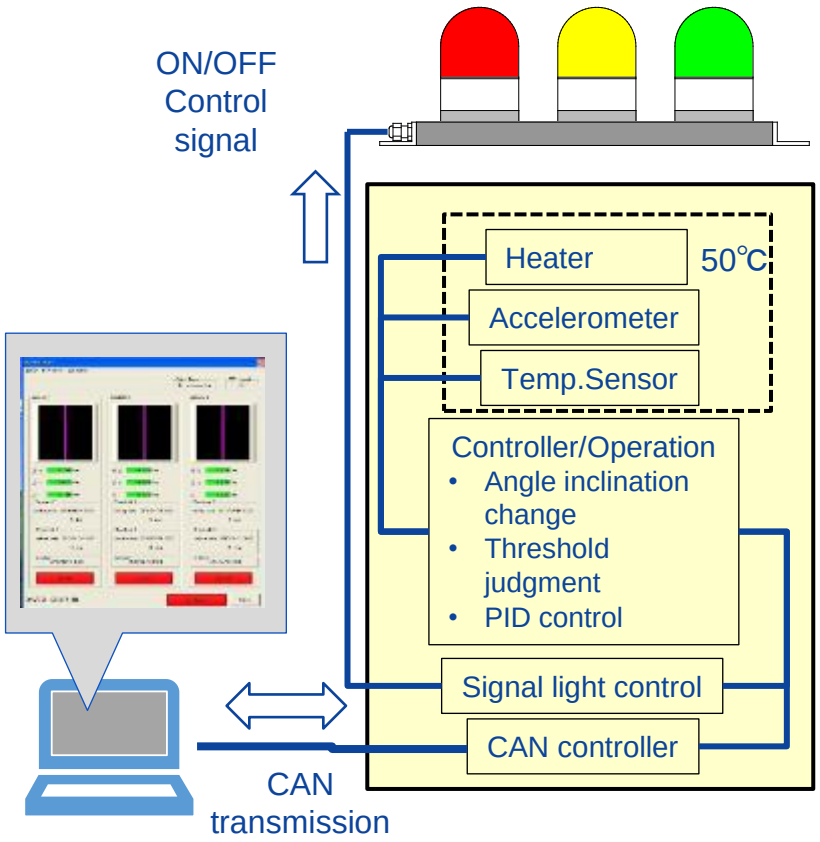
5-1) Monitoring bridge construction



A bridge girder was monitored as it got longer on each side. Every time concrete is casted on either side, the girder inclines responding to a new weight balance. The Light Emitting Inclination Sensors were installed to make sure that the inclination experienced during the construction process was within allowable range.

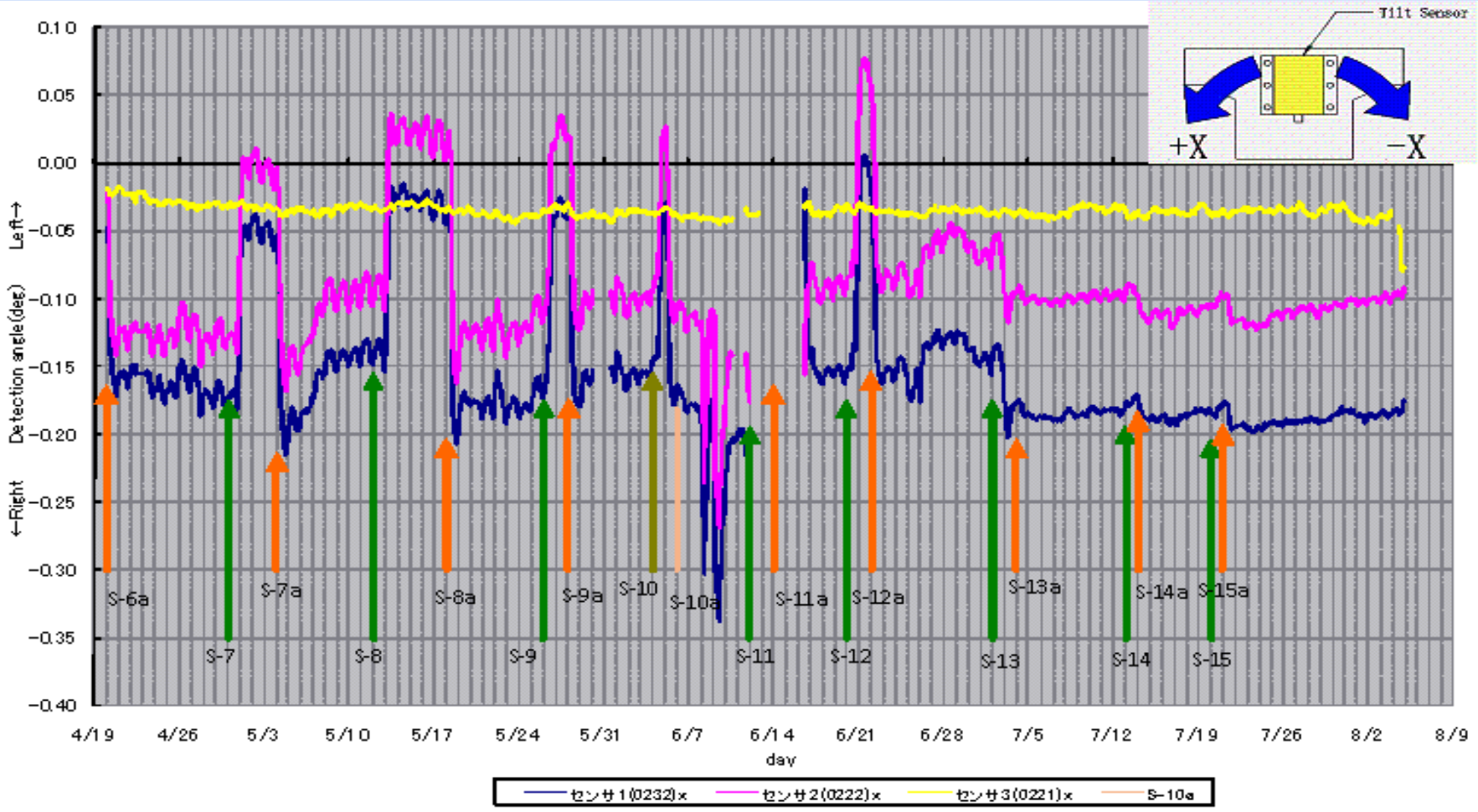

5-1) Monitoring bridge construction

5-1) Monitoring bridge construction



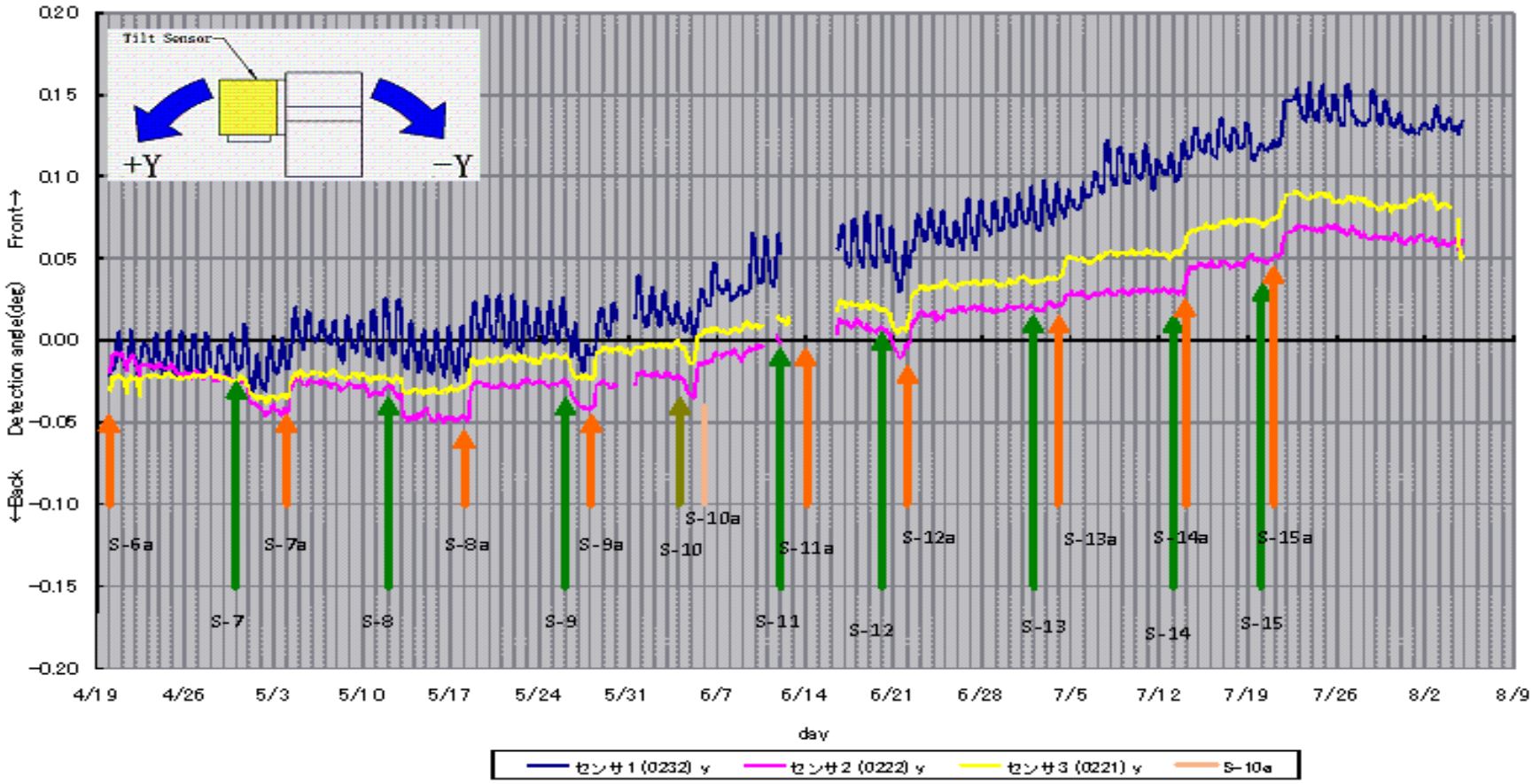
Item	Specification	Note
Measurement axes	2	X,Y direction
Measurement range	±20 deg	
Angle change method	Capacitance type accelerometer	
Temperature change method	IC temperature sensor	
Rated value output	40000 digit	
Resolution	1/1000 deg	During heater operation
Nonlinearity	0.5% RO	
Mutual interference	5%	
Sampling frequency	1 Hz	
Usage temperature range	-30 ～ +60	
Save temperature range	-30 ～ +80	
Inner heater temperature	50 ±0.5 ℃	
Power consumption	Under 30W	
Rated input voltage	DC24V±1V	
Transmission method	CAN Ver2.0 125Kbps	
Signal light	3 Port DC24V	Green/Yellow/Red

5-1) Monitoring bridge construction



The inclination behavior of the girder was in accordance with the expectation from design stage. However, the actual magnitude of angle change was more than expected.

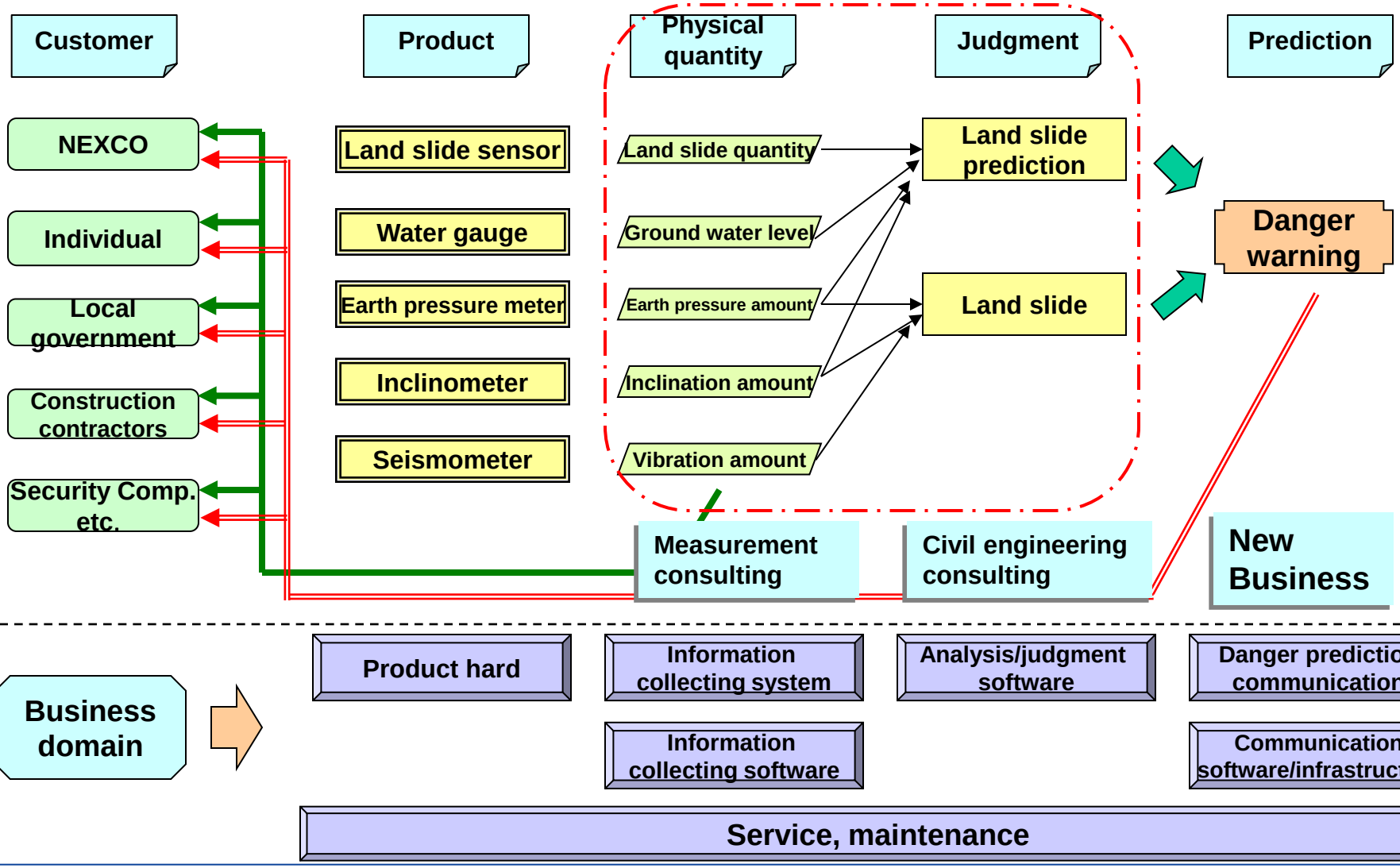
5-1) Monitoring bridge construction



The inclination of the pier, which was initially anticipated to be negligible, was found to be NOT negligible. Its general trend suggested that the pier slowly but constantly tilted toward the inside the bridge curvature with the radius of 300m.

6) Proposal for business model

Provide Safety, relief with information and devices



Thank you.