Design and Deployment of IoT Devices: from Edge to Data Centers

GTek ENTERPRISE

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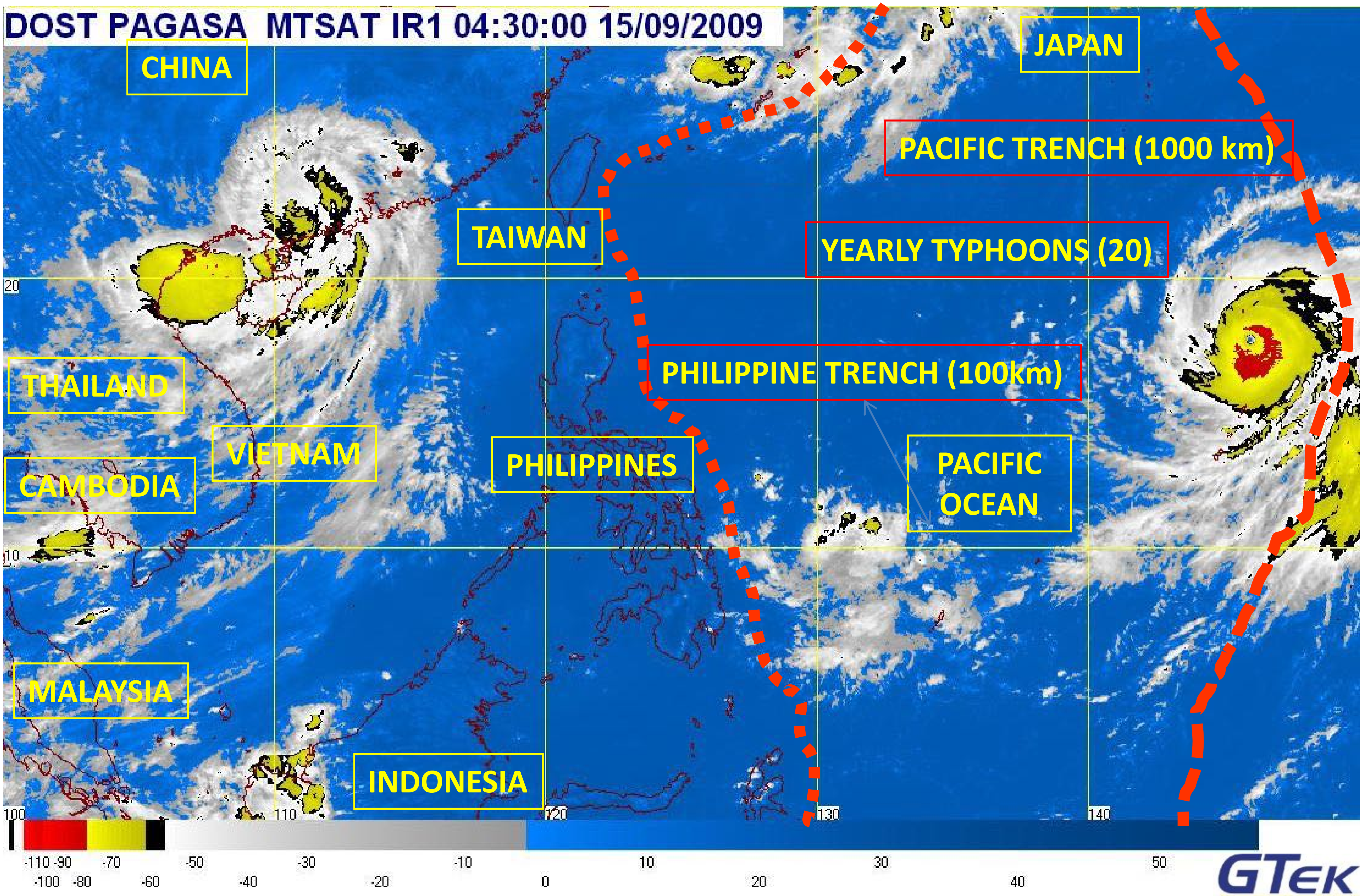
Outline

1. IoT Motivations: Real-world Applications

2. Design and Deployment of Wireless Sensor Networks + IoT

3. Design and Deployment of IoT+TinyML

Motivations: Real-world Applications



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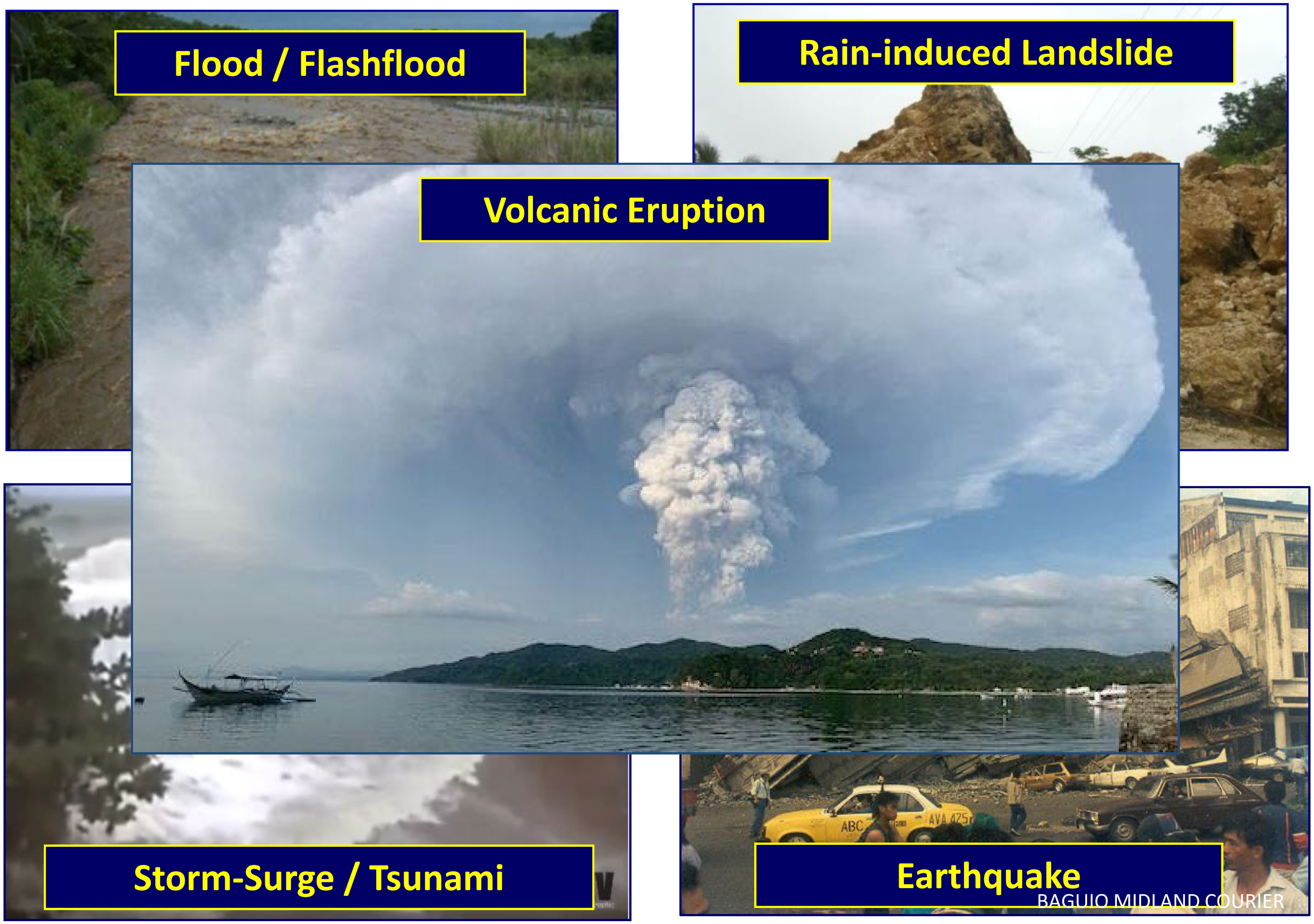
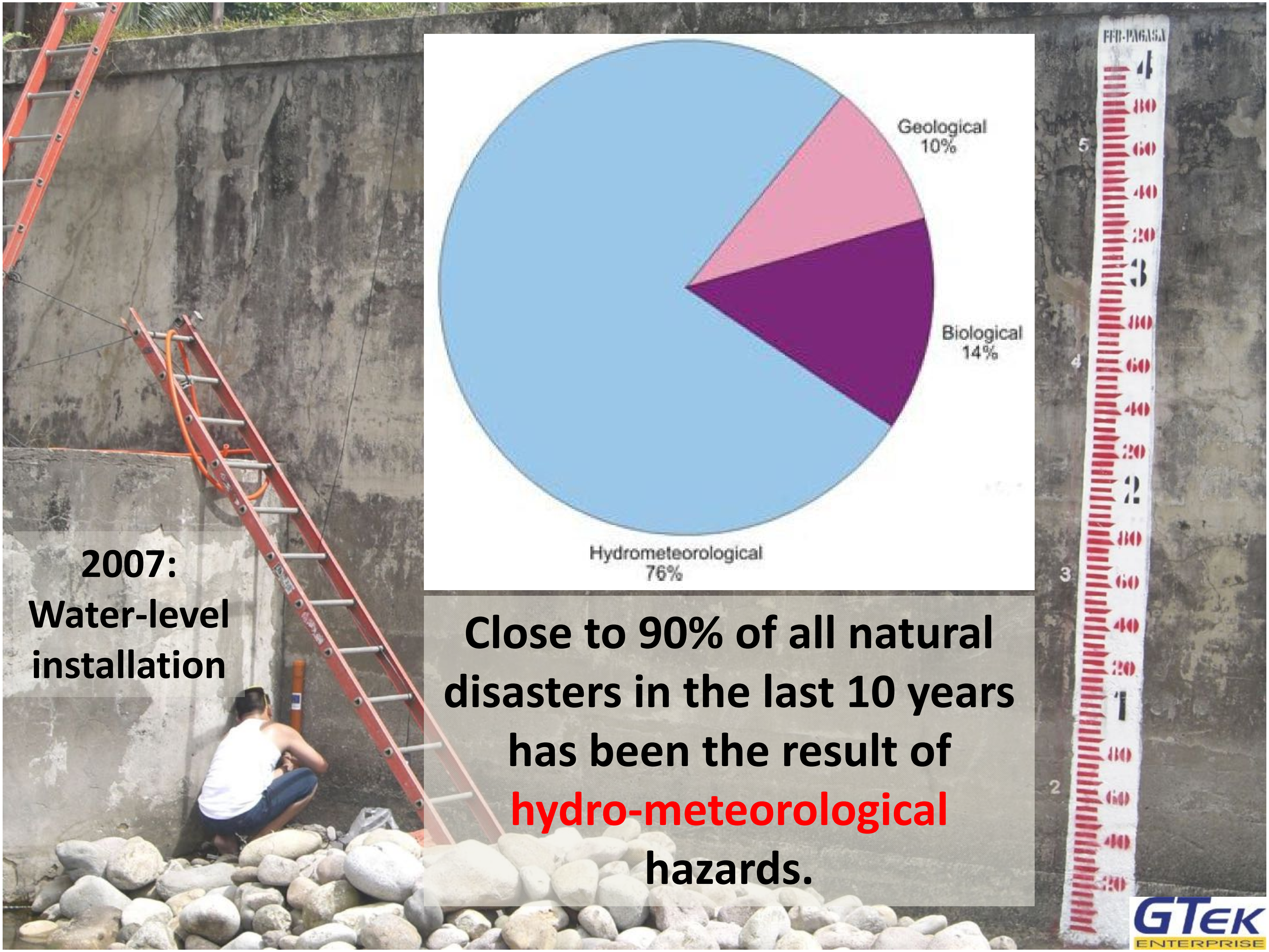
NATURAL DISASTERS… WAITING TO HAPPEN.



The grim devastation wrought by the catastrophic flashflood in Ormoc, Leyte, Philippines. In November 1991, more than 5000 people perished in this single tragedy. Unusually heavy, continuous rains (580.5 millimeters in 24 hours) brought by tropical storm Uring caused landslides at the steep slope of a river system leading to the city of Ormoc.

A massive mudslide occurred in Saint Bernard on February 17, 2006 in the Philippine province of Southern Leyte that caused widespread damage and loss of life. The deadly landslide followed a ten-day period of heavy rains and a minor earthquake of magnitude 2.6 on the Richter scale. The official death toll stands at 1,126.



2007: Water-level installation

Close to 90% of all natural disasters in the last 10 years has been the result of hydro-meteorological hazards.


Anyone could be a victim of a disaster!
= Unaware + Unprepared
Guinsaugon Landslide
Death Toll: 1,126
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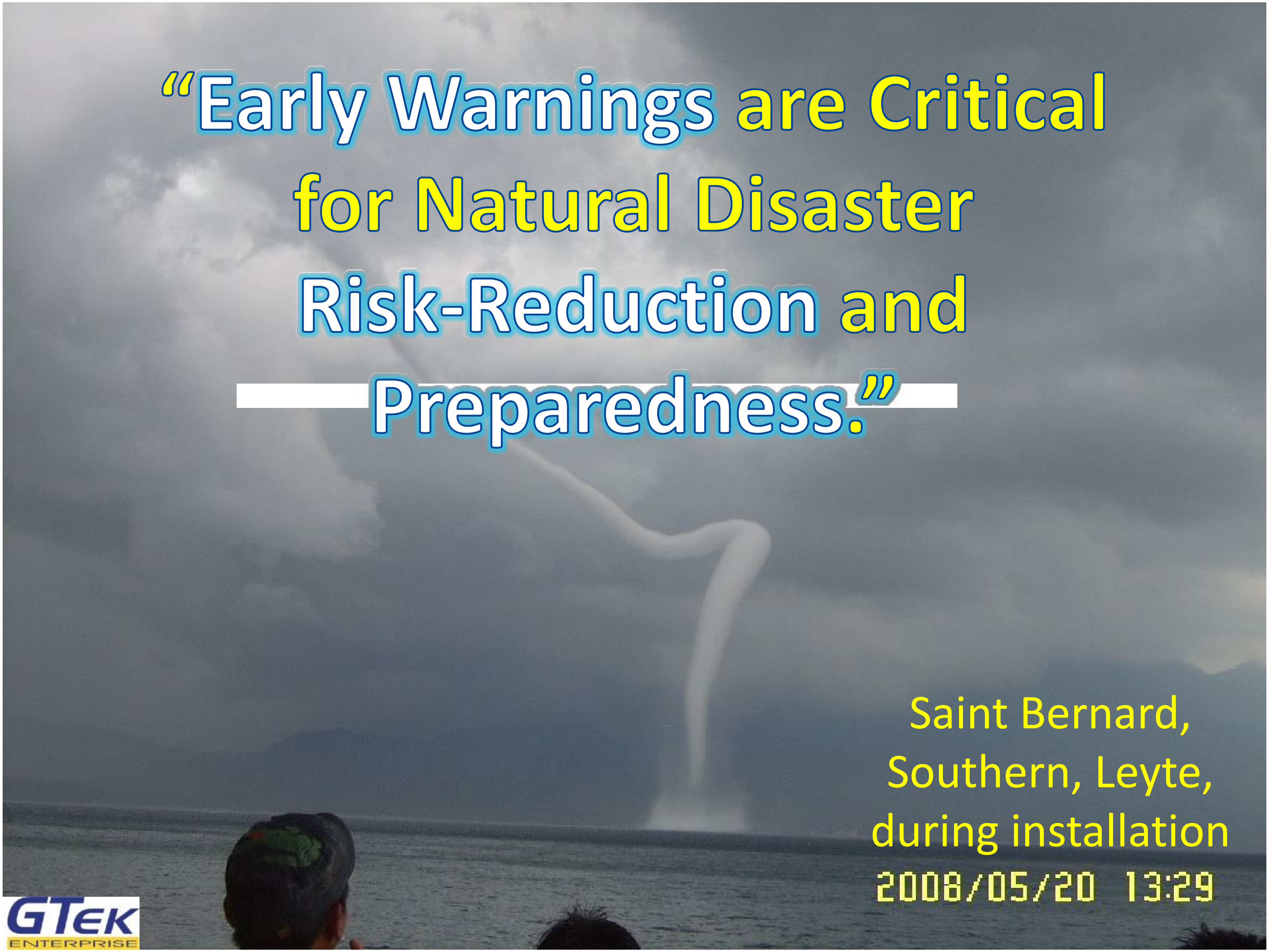
To Protect Yourself =

(Right Information + Right Plan) x (Enough Lead-time)


"Early Warnings are Critical for Natural Disaster Risk-Reduction and Preparedness."
Saint Bernard, Southern, Leyte, during installation
2008/05/20 13:29

Citizens' Interviews

Solution:

Radio Propagation Survey

Community-Based Disaster Early Warning System

Rainfall Gauge

Water-level Gauge

There is a need to Implement Hydro-Meteorological Data Monitoring and early Warning System

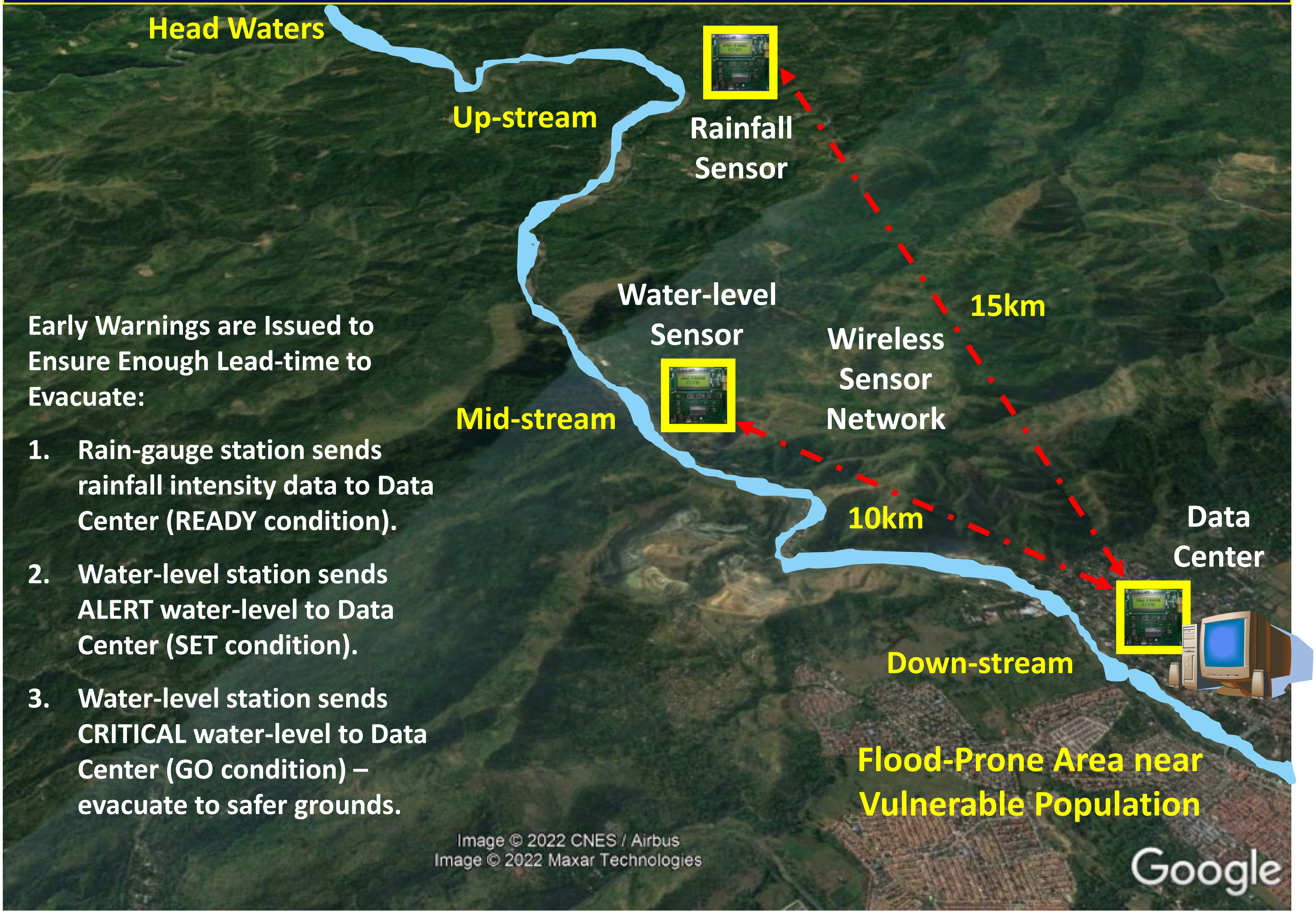
Objectives:

1. To warn the authorities and vulnerable population ahead of time of any threat of flood/flashflood and landslide.

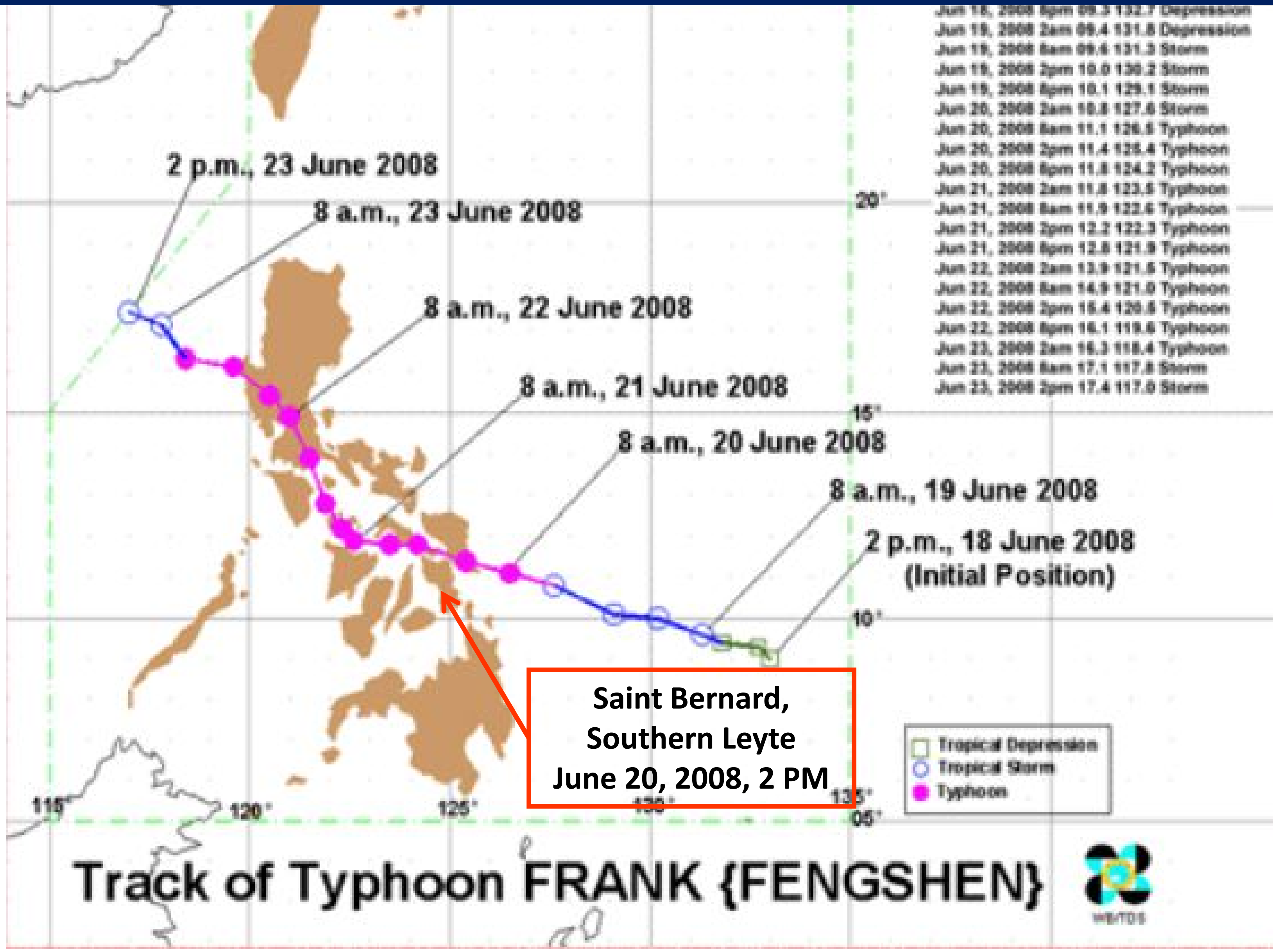
2. To provide enough lead-time between a critical warning and completion of evacuation of lives and properties to safer grounds.

3. To collect data about river system characteristics (rainfall intensity and water-level) for research and creating mathematical models of the river system.

Community Based Flood Early Warning System (CBFEWS) Model



The Real Test for my Early Warning System was in June 20, 2008



SAVED 474 PEOPLE

ABOUT 100 FAMILIES WERE PROTECTED FROM A DEVASTATING FLASHFLOOD CAUSED BY TYPHOON FRANK ON JUNE 20, 2008.

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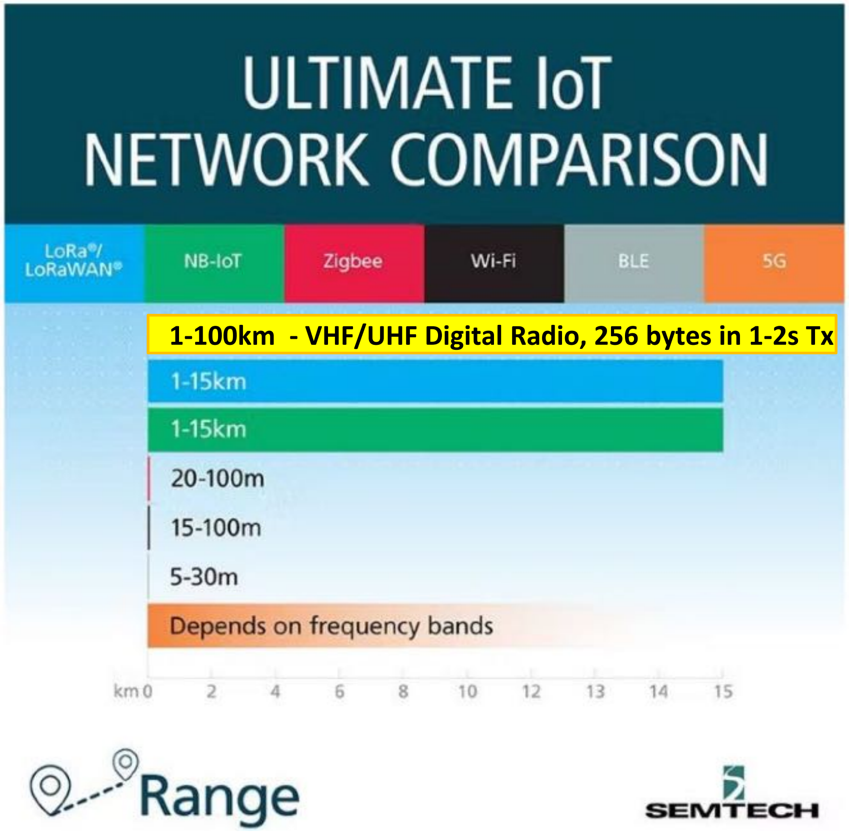
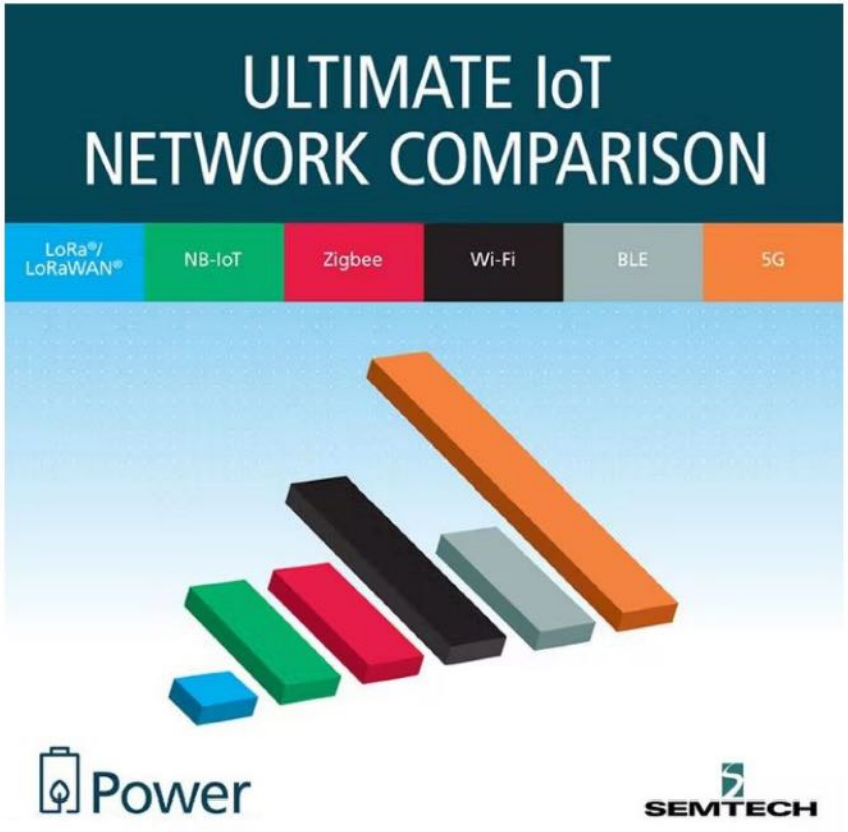
Design of IoT Devices and Networks

Choose the best wireless technology for your application:

Best for IoT = Low_Power + Long_Range + Small

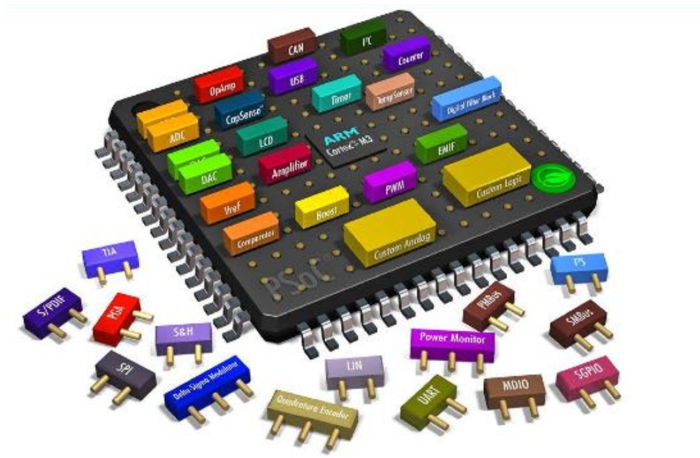




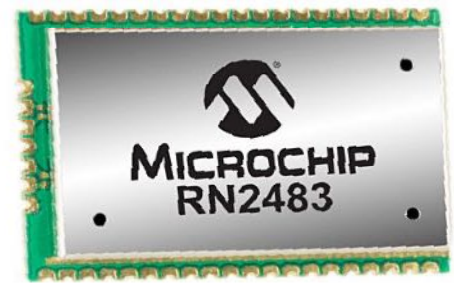
Comparing the power usage between six IoT network technologies.

NB-IoT: https://www.gsma.com/iot/narrow-band-internet-of-things-nb-iot/

Design with PSoC + Dual Core Controllers + LoRA



+



PSoC 5 LP: 1-Core
ARM Cortex -M3 (80 MHz)

PSoC 6: 2-Cores
ARM Cortex -M4 (150 MHz) +
ARM Cortex -M0+ (100 MHz)

RN2483 LoRa Module

- On-board LoRaWAN protocol stack
- ASCII command interface over UART
- Output Power (dBm), 14.00
- Dual band 433 MHz, 868 MHz
- Rx Input Sensitivity (dB), -148
- Current: Tx = 40mA, Rx = 14.2mA
- Single Operating Voltage: 2.1V to 3.6V

IoT (Internet-of-Things) + TinyML Solution

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Benefits of Designing your Own IoT Device

Benefits of Designing your own HW:

- Customized = Optimized Functions
- System-on-Chip / Dual Core = Do more with less (1 chip) = Lower HW Cost

Benefits of Coding your own SW Protocols:

- Reprogrammability = Flexibility
- Adding Specialized SW functions = Lower Overall System's Cost

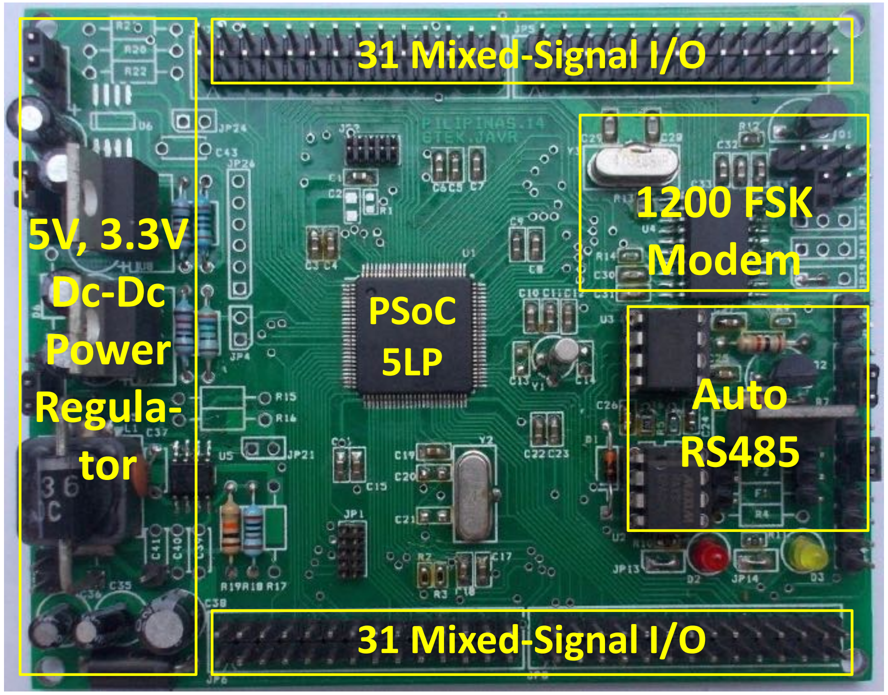
Combined Benefits:

- Reliability, Maintainability, Sustainability = Longer System's Useful Life

Embedded PSoC-Based Controller (2014)

SENSORS:

- WATER LEVEL
- RAINFALL INTENSITY
- TEMPERATURE & HUMIDITY
- PRESSURE / ALTITUDE
- PROXIMITY / MAGNETIC
- AUTOMATIC WEATHER STATION (AWS)
- VOLTAGE, CURRENT, & POWER
- LIGHT INTENSITY
- ACCELERATION / EARTHQUAKE
- INCLINATION / TILT
- TOXIC GAS / CHEMICAL
- LIGHTNING INTENSITY & RANGE



DATA TRANSCEIVERS:

- VHF / UHF
- LoRa
- SMS-GSM
- ISM (SUB 1-GHZ BANDS)

DESIGNED FOR MULTI-HAZARD EWS APPLICATIONS:

- FLOOD EWS (FEWS)
- LANDSLIDE EWS (LEWS)
- TSUNAMI & STORM SURGE EWS (TSSEWS)

INTERFACES:

- COMPUTER
- ETHERNET , WIFI
- GPS, BLUETOOTH
- ZIGBEE

POWER SOURCES:

- SOLAR
- WIND
- BATTERY / DC
- AC

NON-VOLATILE MEMORIES:

- SD CARD
- FLASH / EEPROM
- DATA LOGGER

WARNING INDICATORS:

- SIREN / BUZZER
- BEACON LIGHT
- LCD / LED

Single HW design for many applications

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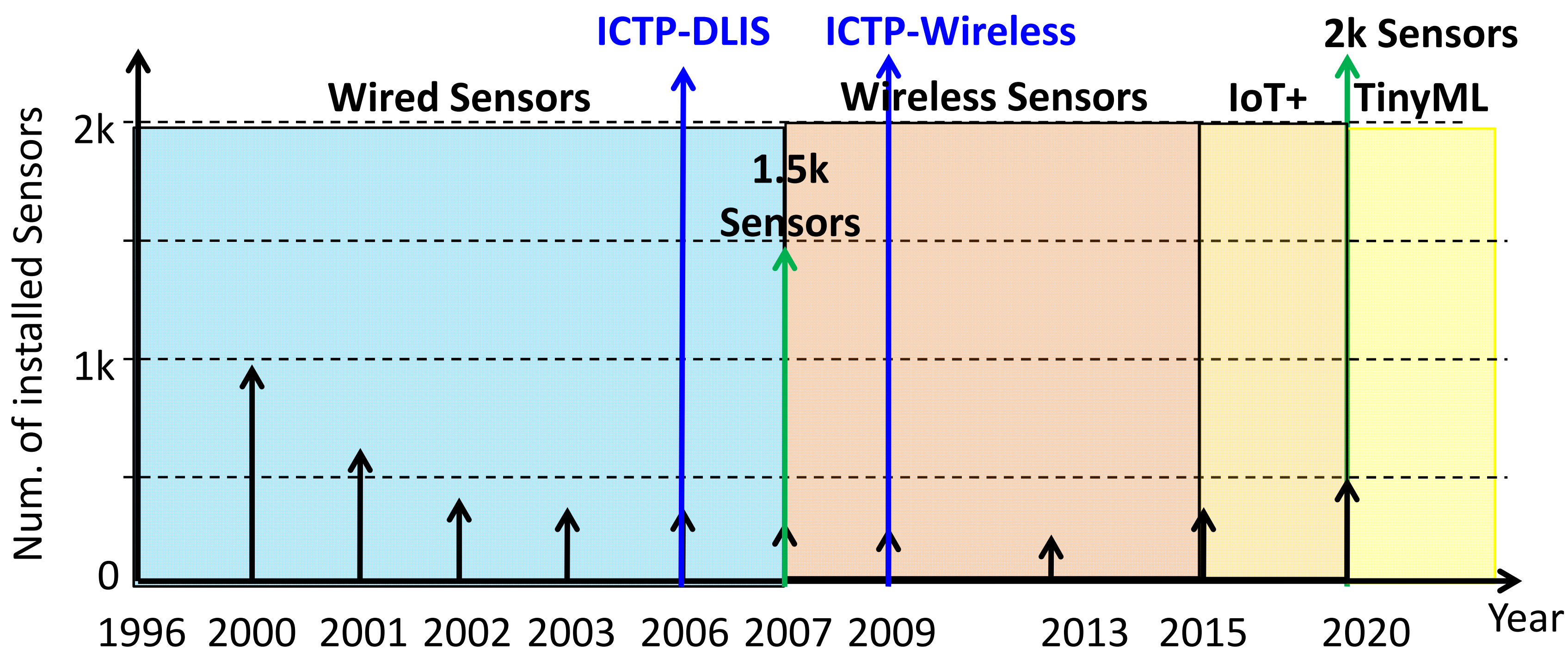
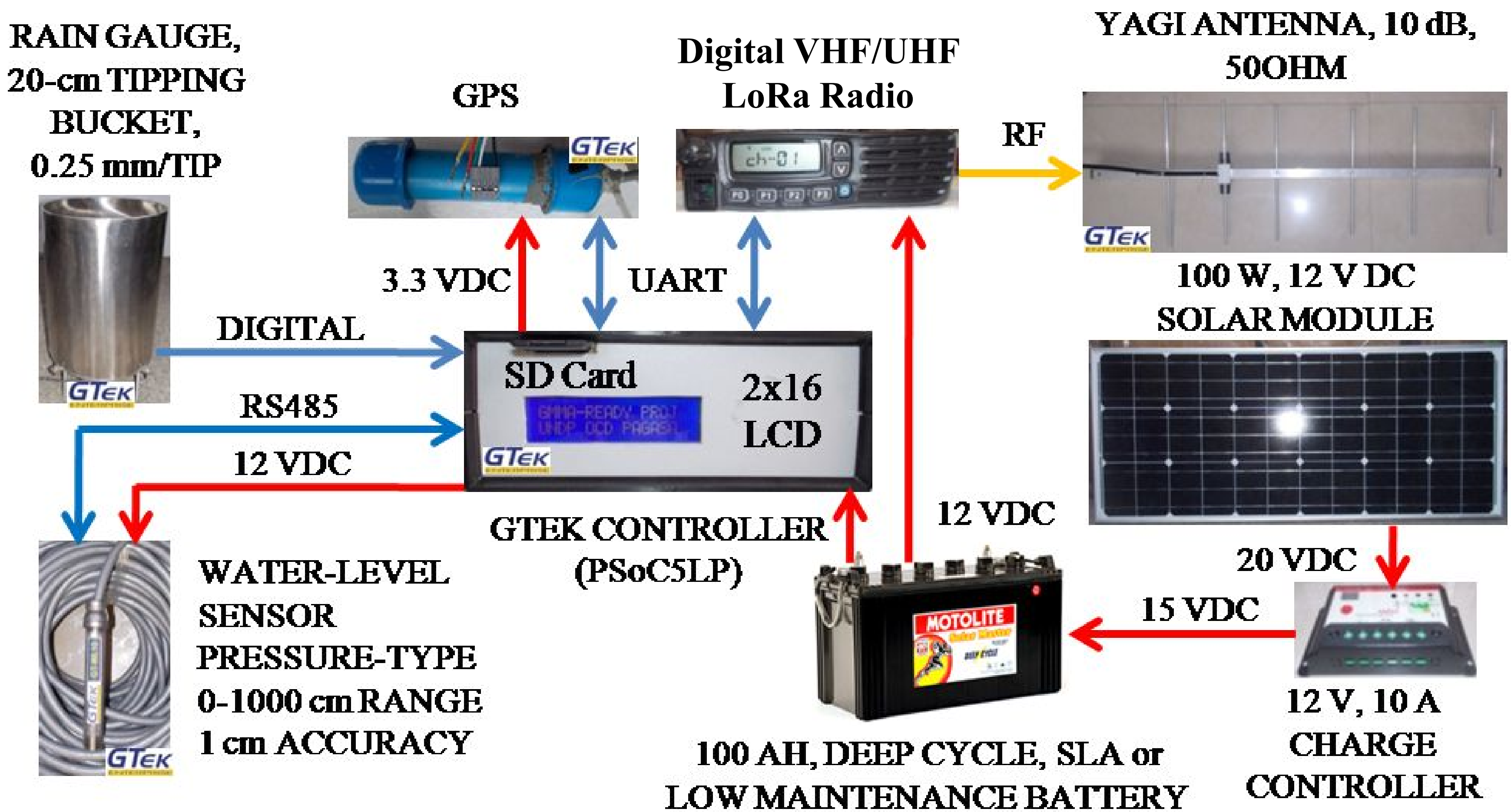
Deployment: From Wired Sensor Networks to IoT + TinyML Networks



Projects:

Semiconductor and Electronics Manufacturing, and Automated Test Industries: Pacific Semi, Philips Semi, Intel, Cypress Semi, Data General, Acbel Polytech, Amkor-Anam	**Disaster Mitigation, Environmental, and Research Applications:** Philippine Weather Agency, National Power Corporation, National Water Resources Board, German International Cooperation, World Vision, Action Against Hunger, UNDP, ASEAN IVO

Community-Based Flood Early Warning System Station



CBFEWS Station Equipment Design.

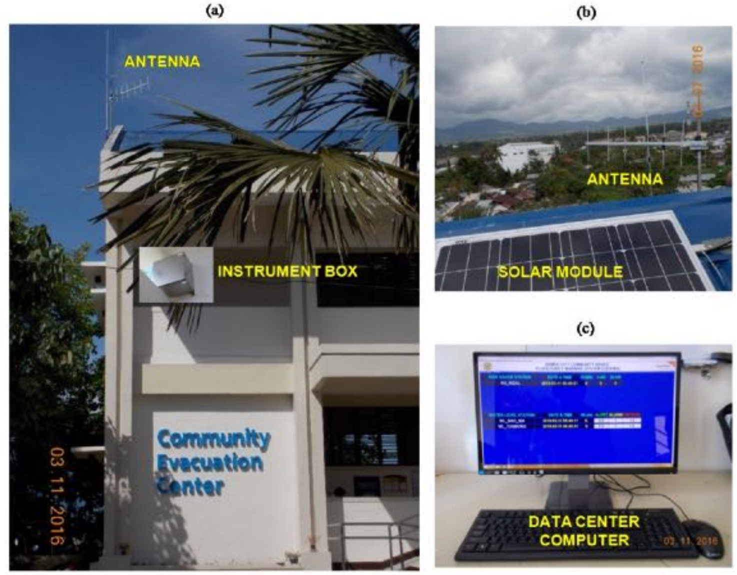
Deployment of Community-Based Flood EW System

Fig. 4. Rain-gauge Installation (a) on frame and (b) on building rooftop.

Fig. 5. Water-level Station Installation (a) on frame and (b) sensor inside a protection metal pipe bolted on bridge column.

Rain Gauge Station

Water-level Station



Data Center Station

Fig. 6. Data Center integrates an (a) instrument box, a (b) solar module, and a (c) data collection computer.

Greater Metro Manila Ready Project (GMMA READY) Sponsored by the UNDP (2015)

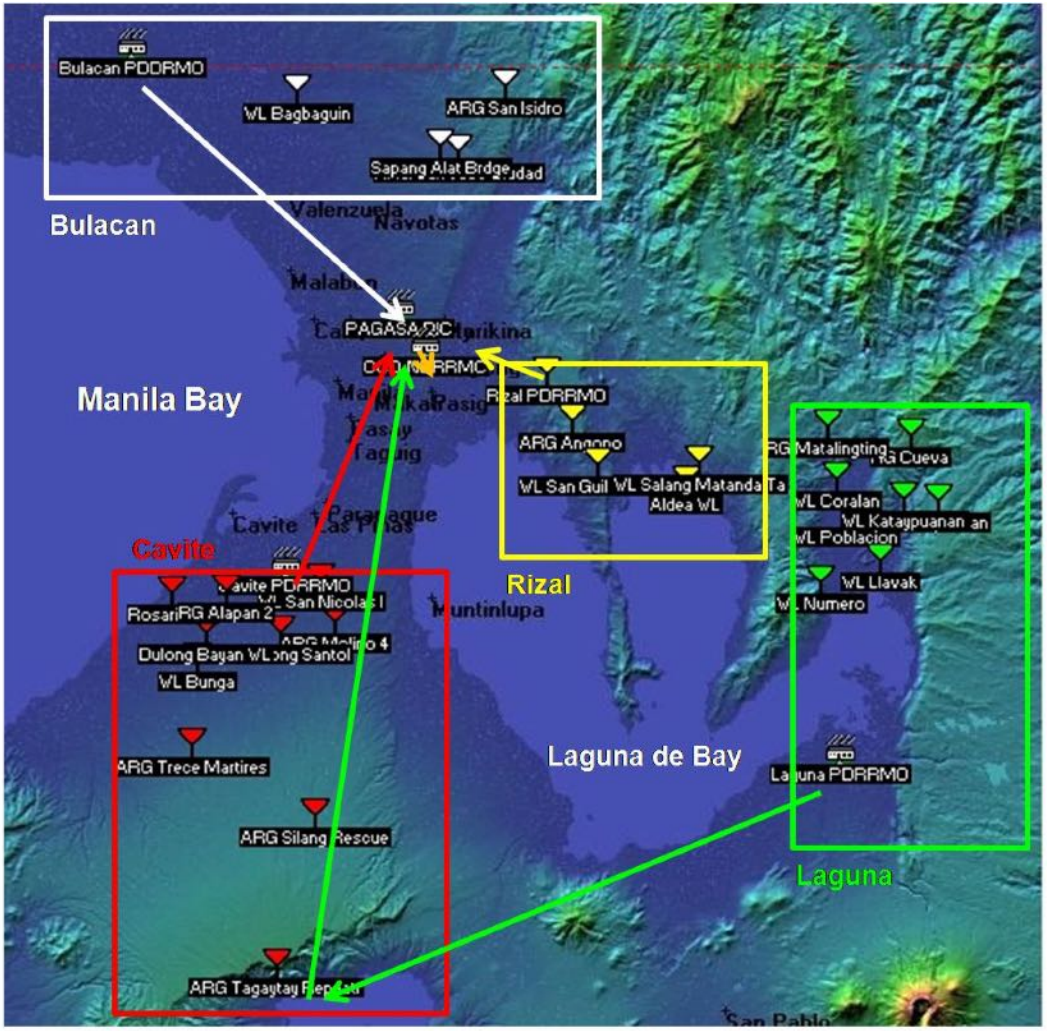
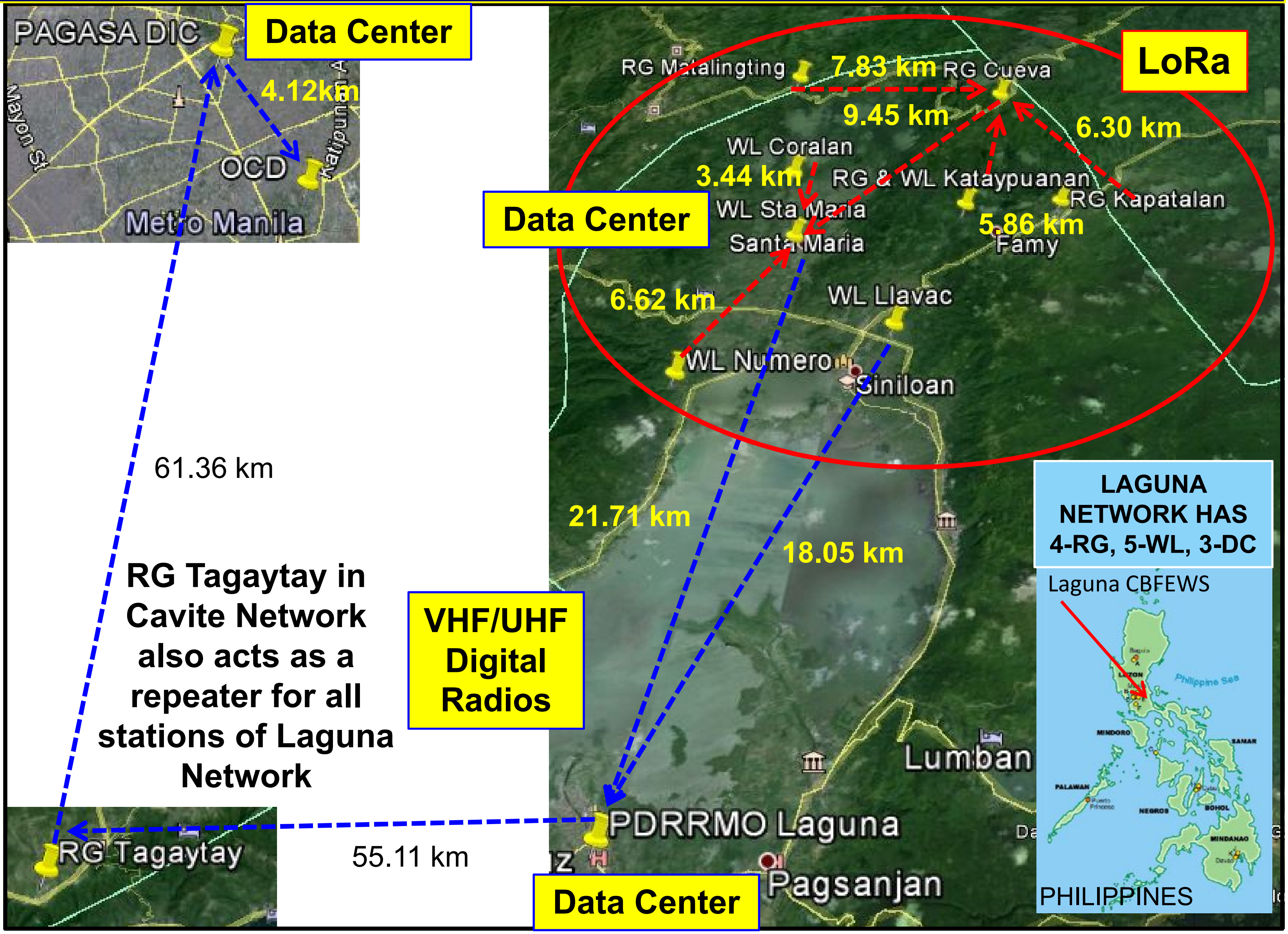
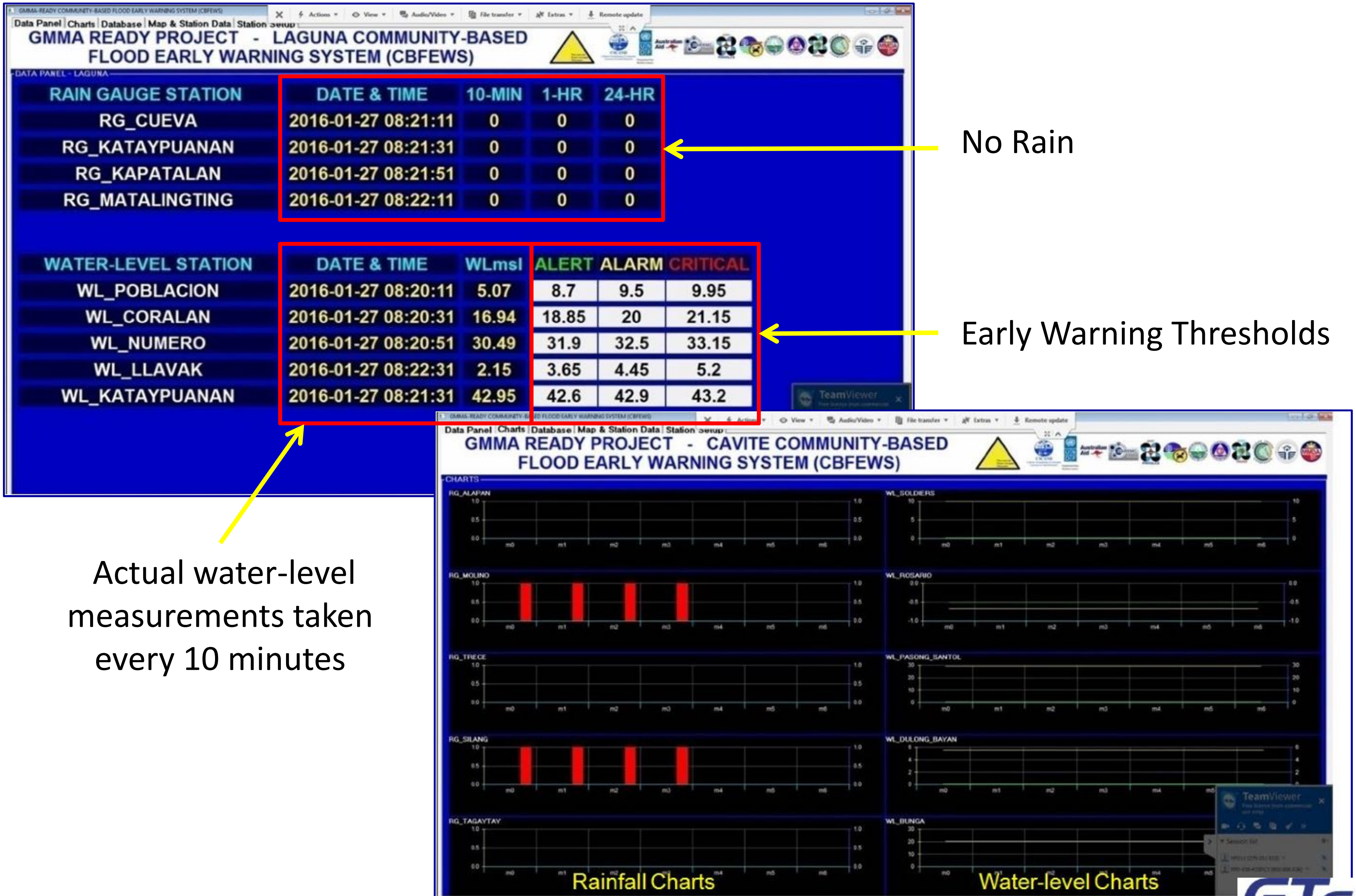


Fig. 7. GMMA-READY CBFEWS Network covers four provinces surrounding Manila, has 34 stations: 15 WL, 13 RG, and 6 DC.

Laguna CBFEWS IoT Network



Data Thresholds and Charts for Early Warning



RAIN GAUGE STATION	DATE & TIME	10-MIN	1-HR	24-HR
RG_CUEVA	2016-01-27 08:21:11	0	0	0
RG_KATAYPUANAN	2016-01-27 08:21:31	0	0	0
RG_KAPATALAN	2016-01-27 08:21:51	0	0	0
RG_MATALINGTING	2016-01-27 08:22:11	0	0	0

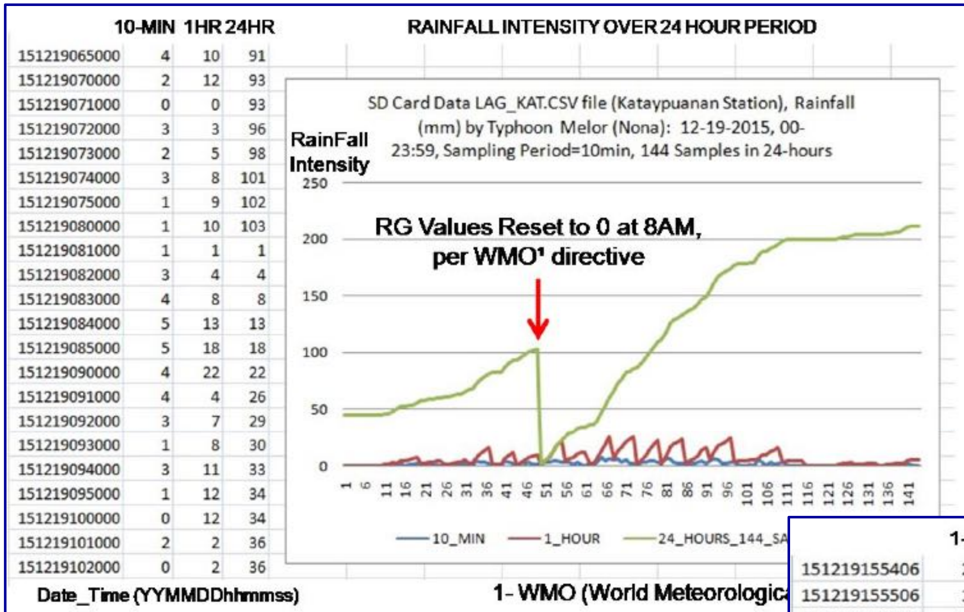
WATER-LEVEL STATION	DATE & TIME	WLmsl	ALERT	ALARM	CRITICAL
WL_POBLACION	2016-01-27 08:20:11	5.07	8.7	9.5	9.95
WL_CORALAN	2016-01-27 08:20:31	16.94	18.85	20	21.15
WL_NUMERO	2016-01-27 08:20:51	30.49	31.9	32.5	33.15
WL_LLAVAK	2016-01-27 08:22:31	2.15	3.65	4.45	5.2
WL_KATAYPUANAN	2016-01-27 08:21:31	42.95	42.6	42.9	43.2

No Rain

Early Warning Thresholds

Actual water-level measurements taken every 10 minutes

Laguna CBFEWS Telemetry Network: Data Collection



	10-MIN	1HR	24HR
151219065000	4	10	91
151219070000	2	12	93
151219071000	0	0	93
151219072000	3	3	96
151219073000	2	5	98
151219074000	3	8	101
151219075000	1	9	102
151219080000	1	10	103
151219081000	1	1	1
151219082000	3	4	4
151219083000	4	8	8
151219084000	5	13	13
151219085000	5	18	18
151219090000	4	22	22
151219091000	4	4	26
151219092000	3	7	29
151219093000	1	8	30
151219094000	3	11	33
151219095000	1	12	34
151219100000	0	12	34
151219101000	2	2	36
151219102000	0	2	36

Rainfall Intensity (mm)

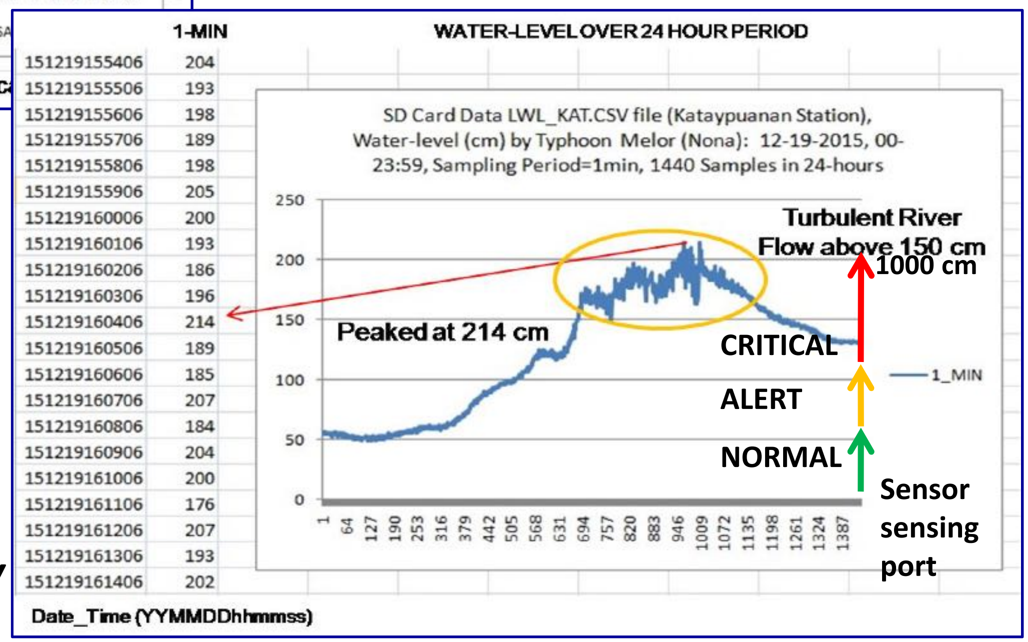
- 10-MIN
- 1HR
- 24HR

Flood Early Warning Definitions: Warns the people to get READY, SET, and GO to evacuate to safer grounds.

↑ Level 3: 101 cm < Critical, GO

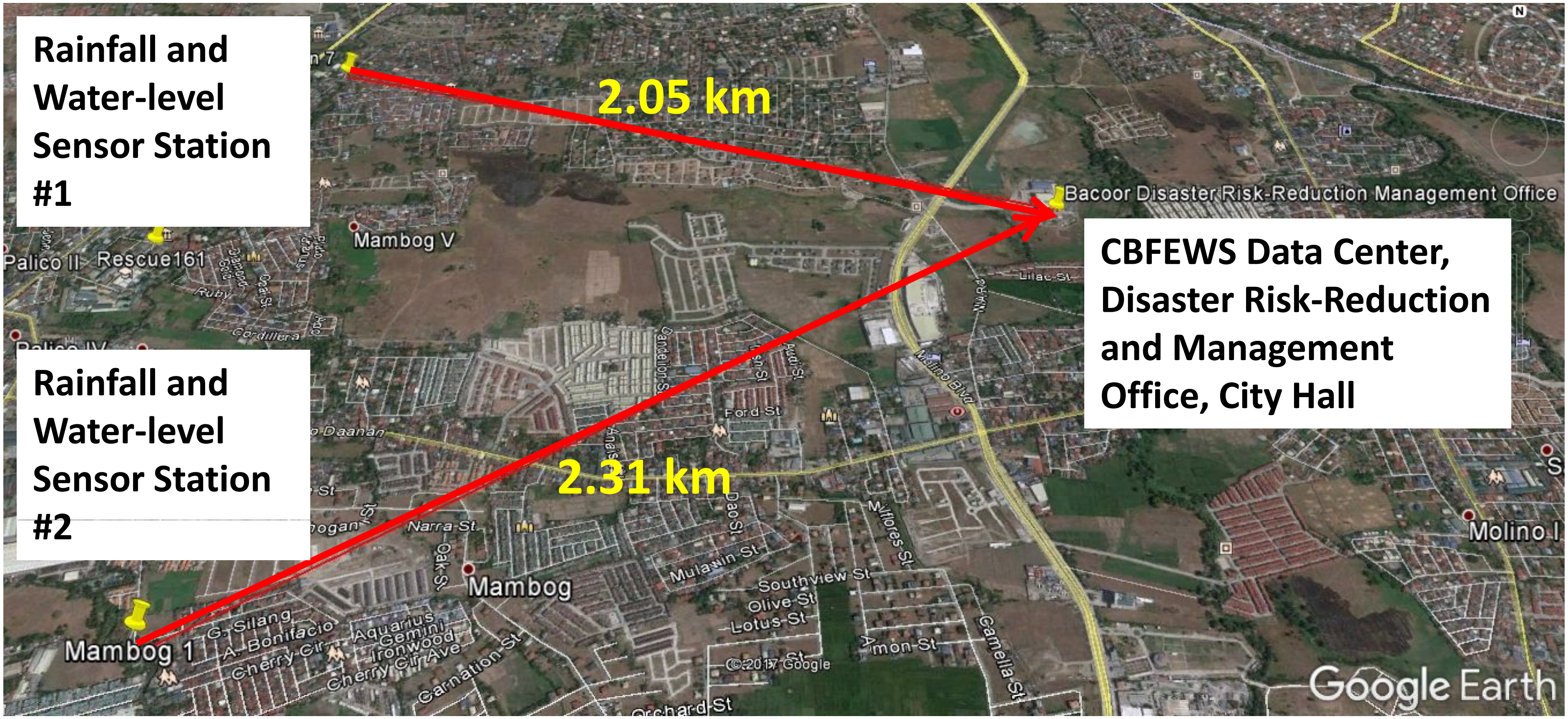
↑ Level 2: 51 cm < Alert <= 100 cm, SET

↑ Level 1: 0 cm < Normal <= 50 cm, READY



	1-MIN
151219155406	204
151219155506	193
151219155606	198
151219155706	189
151219155806	198
151219155906	205
151219160006	200
151219160106	193
151219160206	186
151219160306	196
151219160406	214
151219160506	189
151219160606	185
151219160706	207
151219160806	184
151219160906	204
151219161006	200
151219161106	176
151219161206	207
151219161306	193
151219161406	202

2017: PSoC + LoRa-Based Flood Early Warning System, Bacoor City, Cavite Philippines



- PSoC + LoRa.
- LoRaWAN is operating at 433MHz, 10mW Tx power.
- A GPS synchronizes the 10-minute data transmission.
- Early warnings are issued based on set thresholds.

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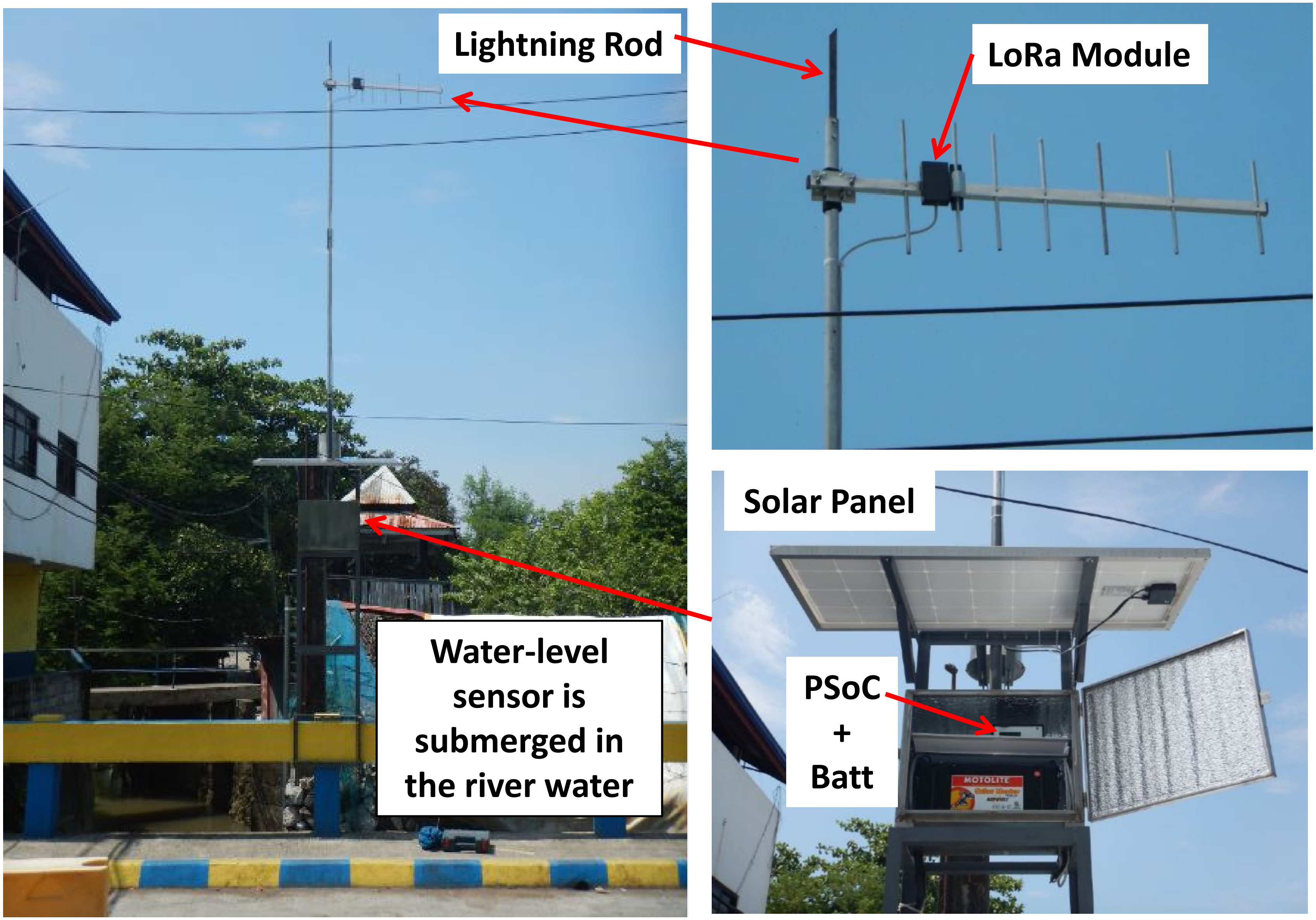
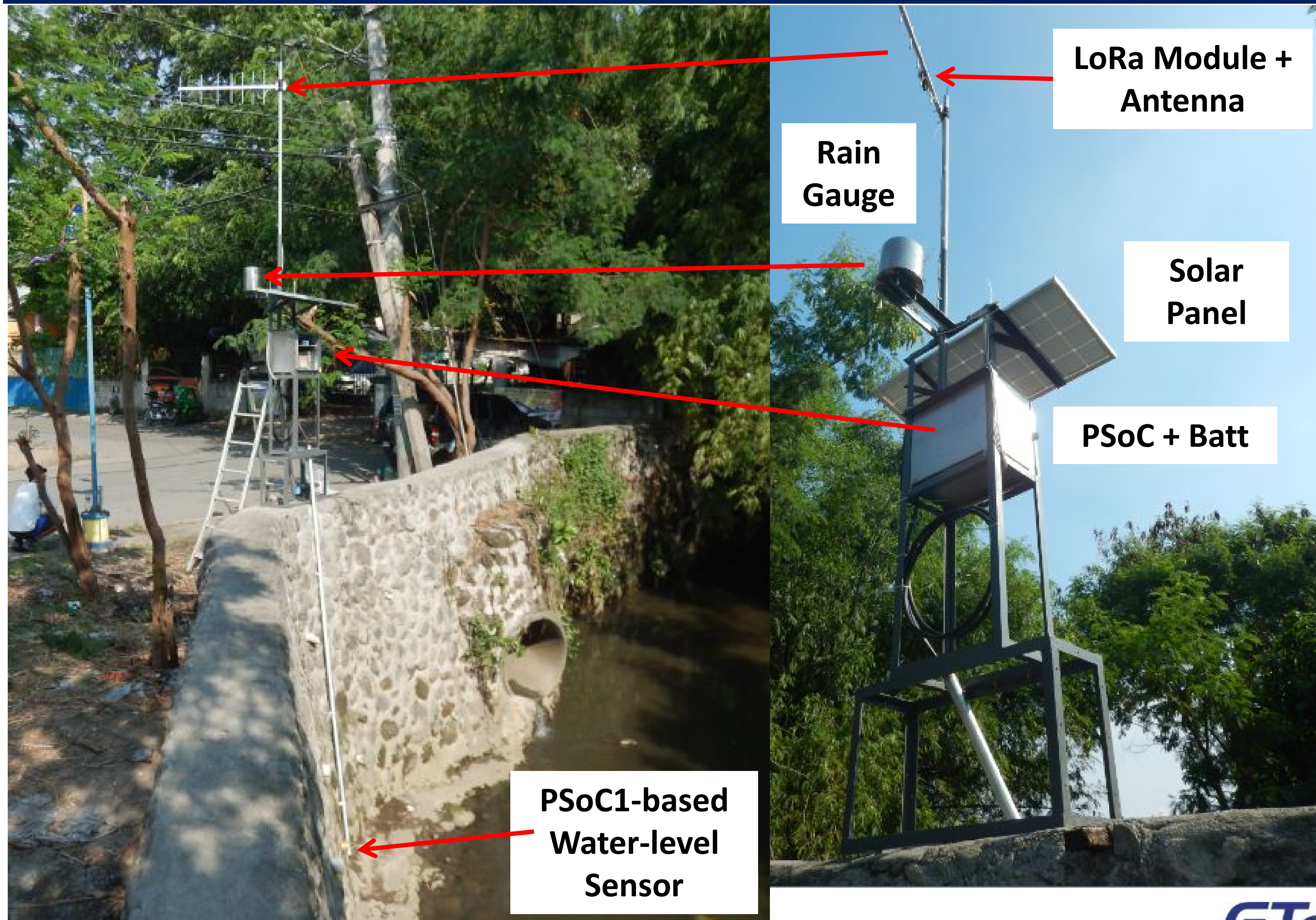
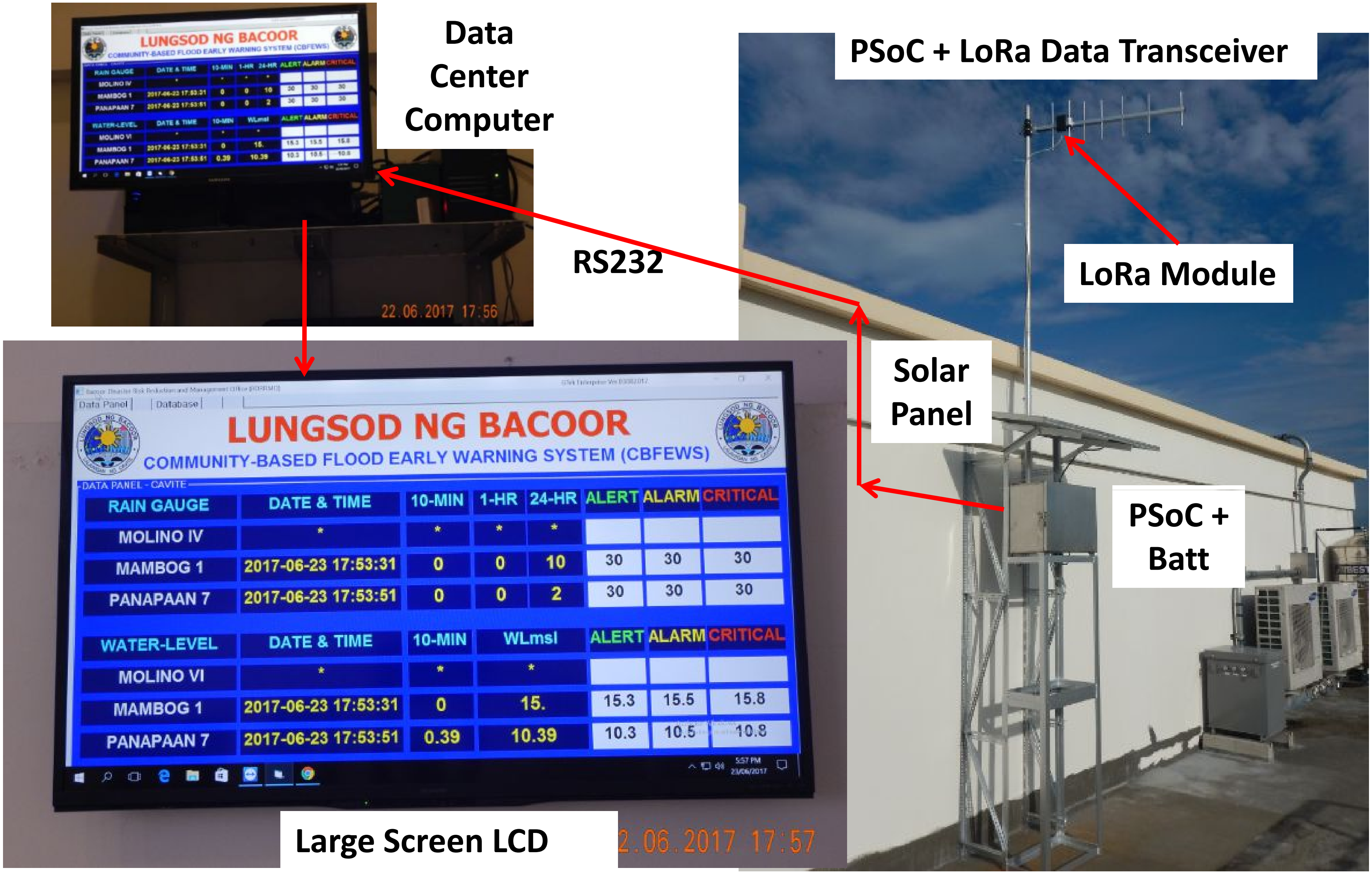
Panapaan 7 Rainfall and Water-Level Gauging Station



Mambog 1 Rainfall and Water-Level Gauging Station



Bacoor Data Center, Disaster Risk-Reduction & Management Office



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2014: Community-Based Landslide Early Warning System (event driven), Maasin City, Southern Leyte, Philippines Sponsored by the German International Cooperation

Sensor Node1

ground crack/m

CBLEWS C
Applic

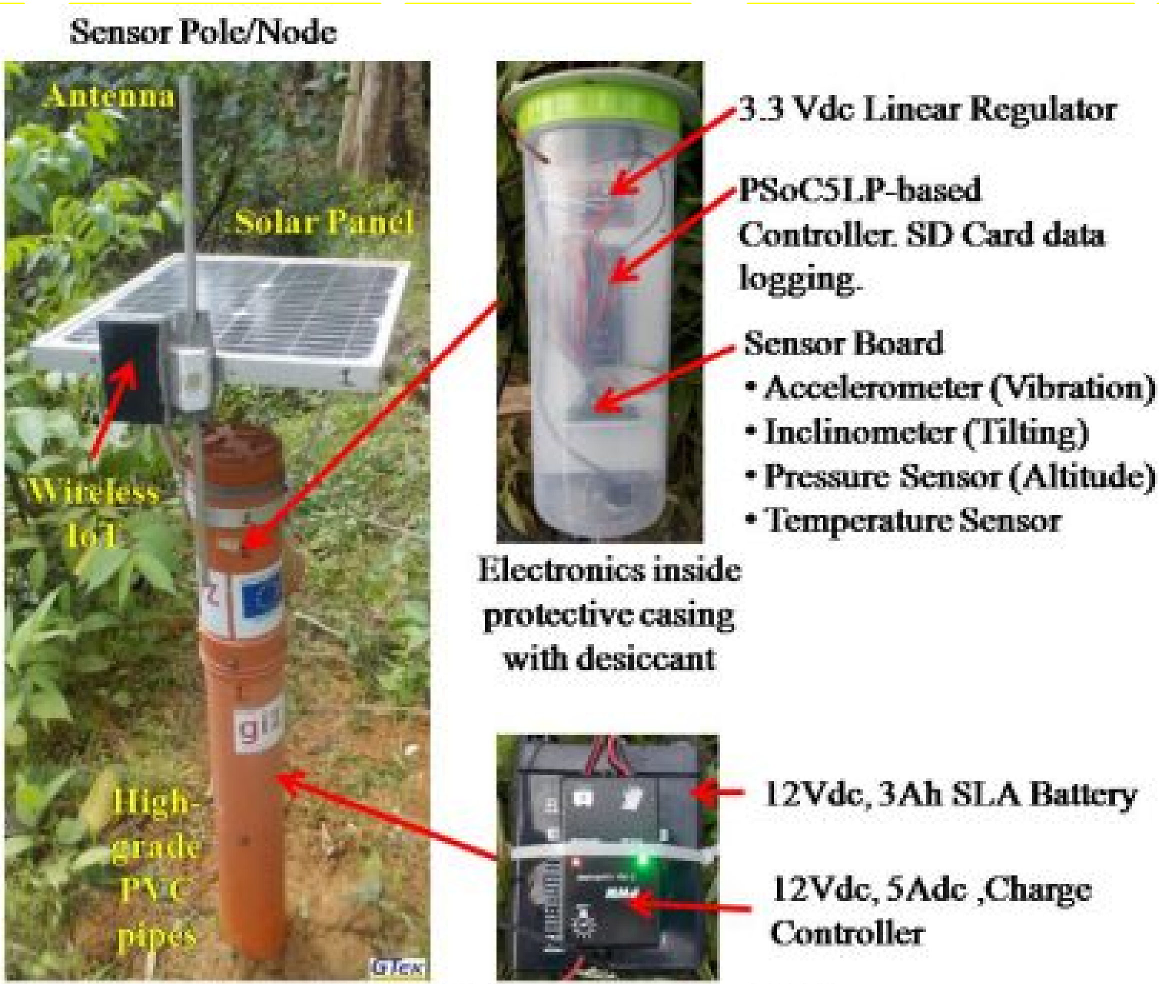


Fig. 22. CBLEWS Landslide Sensor Pole/Node.

Sensor Node5

CBLEWS Gateway

2014: Saving Lives and Properties Through an IoT Network Sponsored by the German International Cooperation

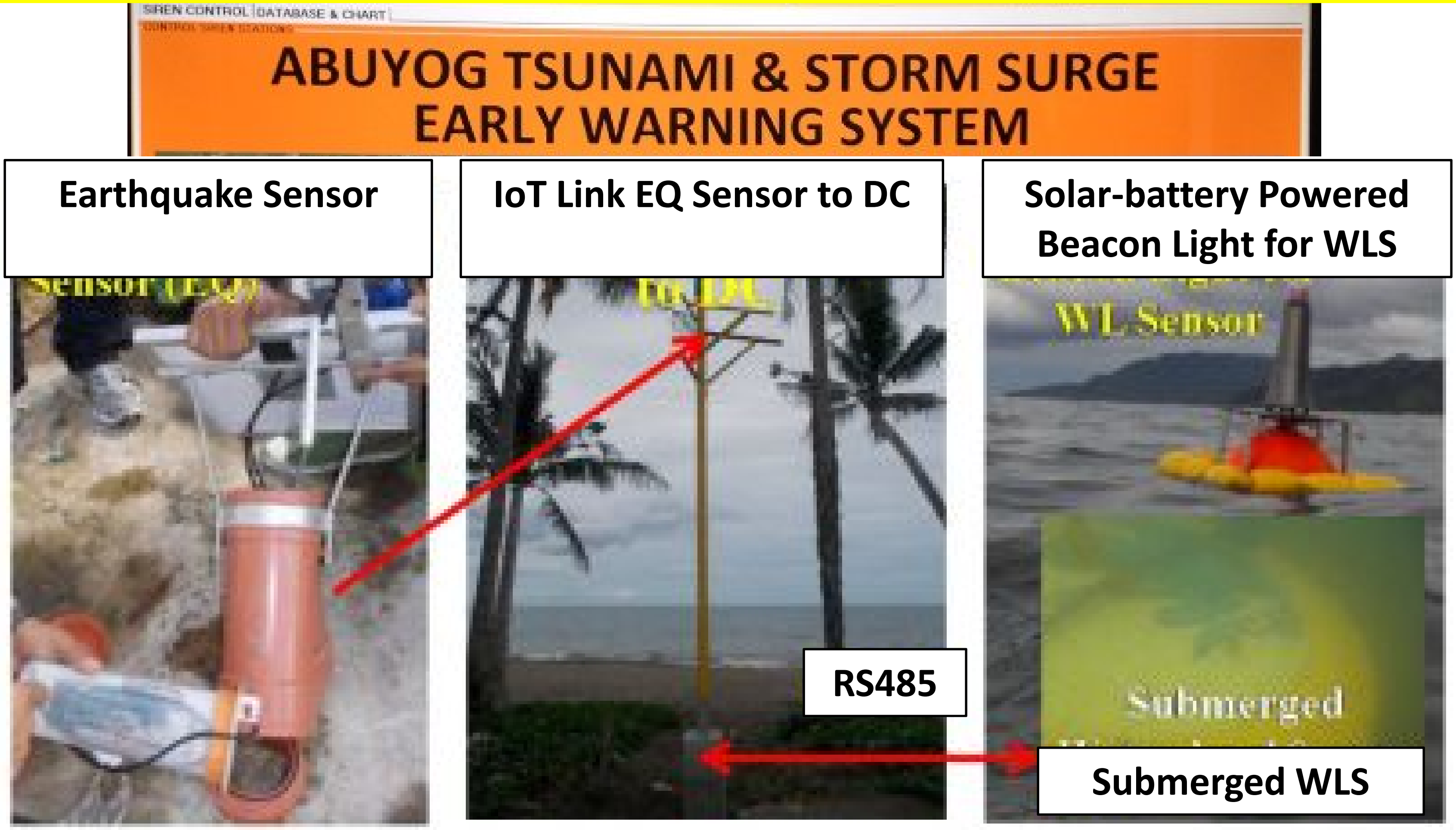


Fig. 26. Integrated Storm-Surge, Earthquake, and Tsunami Sensor

San Sebastian Basilica
Environmental Monitoring System (SSB EMS)

Design, Development, and Implementation of Wireless Sensor Networks Utilising PSoC, LoRa, GPS, and Sensors (Temperature, Humidity, Wind Speed, Wind Direction, and Rainfall Intensity Sensors) for Heritage Conservation

Funded by The Order of the Augustinian Recollects,
United States Department of State through the Ambassador's Fund for Cultural Preservation, and The US Embassy Manila

for

San Sebastian Basilica Conservation and Development Foundation, Inc.

Designed and Developed by
GTek Research
January 2019 - March 2019
Manila

The San Sebastian Basilica,

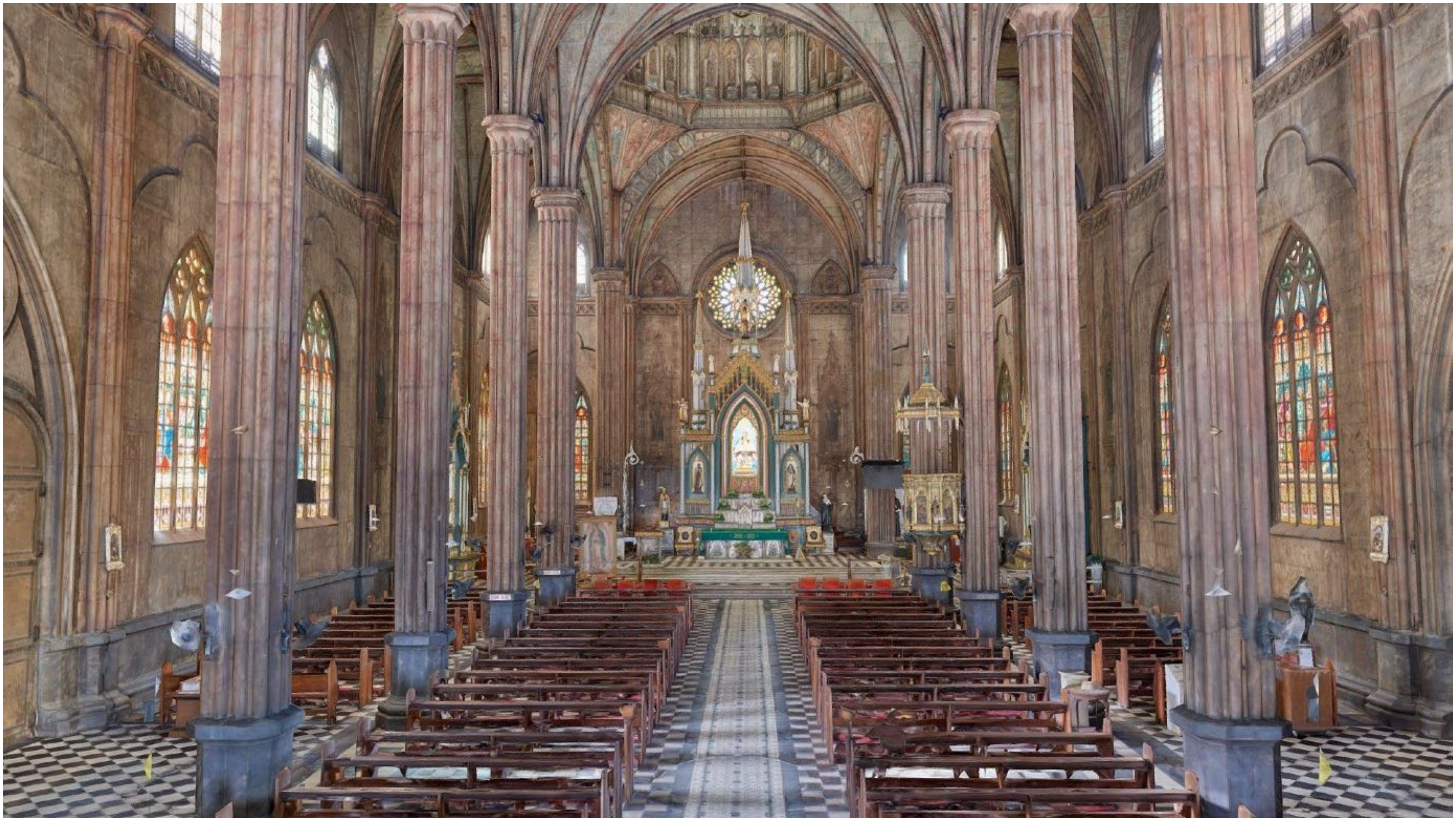
Plaza Del Carmen, Quiapo, Manila, Philippines

An all steel Gothic church completed in 1891, the metals are the same with the ones used with the Eiffel Tower, Paris, which was completed two years earlier in 1889.

The San Sebastian Basilica,

Plaza Del Carmen, Quiapo, Manila, Philippines

https://sketchfab.com/3d-models/san-sebastian-basilica-philippines-d7e29a61d8f842e682aed2e6e9fce5dd



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2012 Projects with San Sebastian Basilica:

Remote-controlled drop-down (30-meters) 8MPixel Point-and Shoot Camera System. Using PSoC, RS485 network, and a laptop.

The column base showing water, and large holes caused by rust

The inside of a column looking down 20 meters. Sequential photographs were taken every quarter meter

Reggie Mercado rigging a system of wires, cables, laptop and camera to look 20 meters down the hollow columns

Dry run: the technical team is glued to the monitor as the camera is lowered to the column base, which has never been seen since construction in 1891. From left: Engineer Reggie Mercado, executive director Tina Paterno, and architect Jonathan Dangue

Walls inclination remote-monitoring using PSoC, precision dual-axis inclination sensors, RS485 network, and a computer

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2019 Project with San Sebastian Basilica
EMS Objectives:

To monitor the Basilica's environmental characteristics in relation to temperature, humidity, rain- induced water, and ambient air/wind.

The collected data will be utilized by a team of mechanical engineers to generate thermal modelling in order to determine whether passive or active cooling method is required.

Leading to:

1) controlling the Basilica's internal temperature and humidity (agents of metal corrosion), and

2) finding the appropriate method to provide cooling effect for church visitors.

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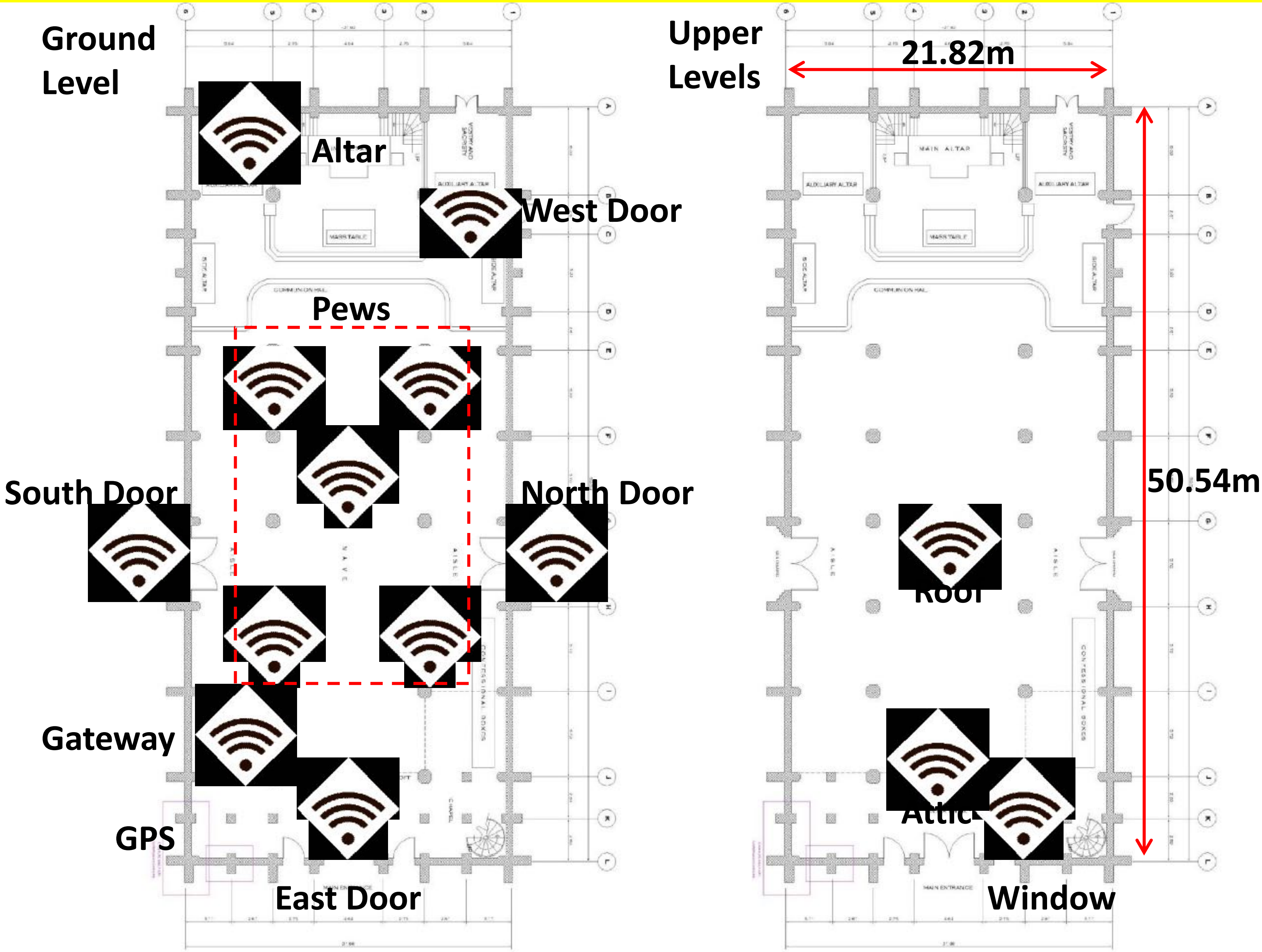
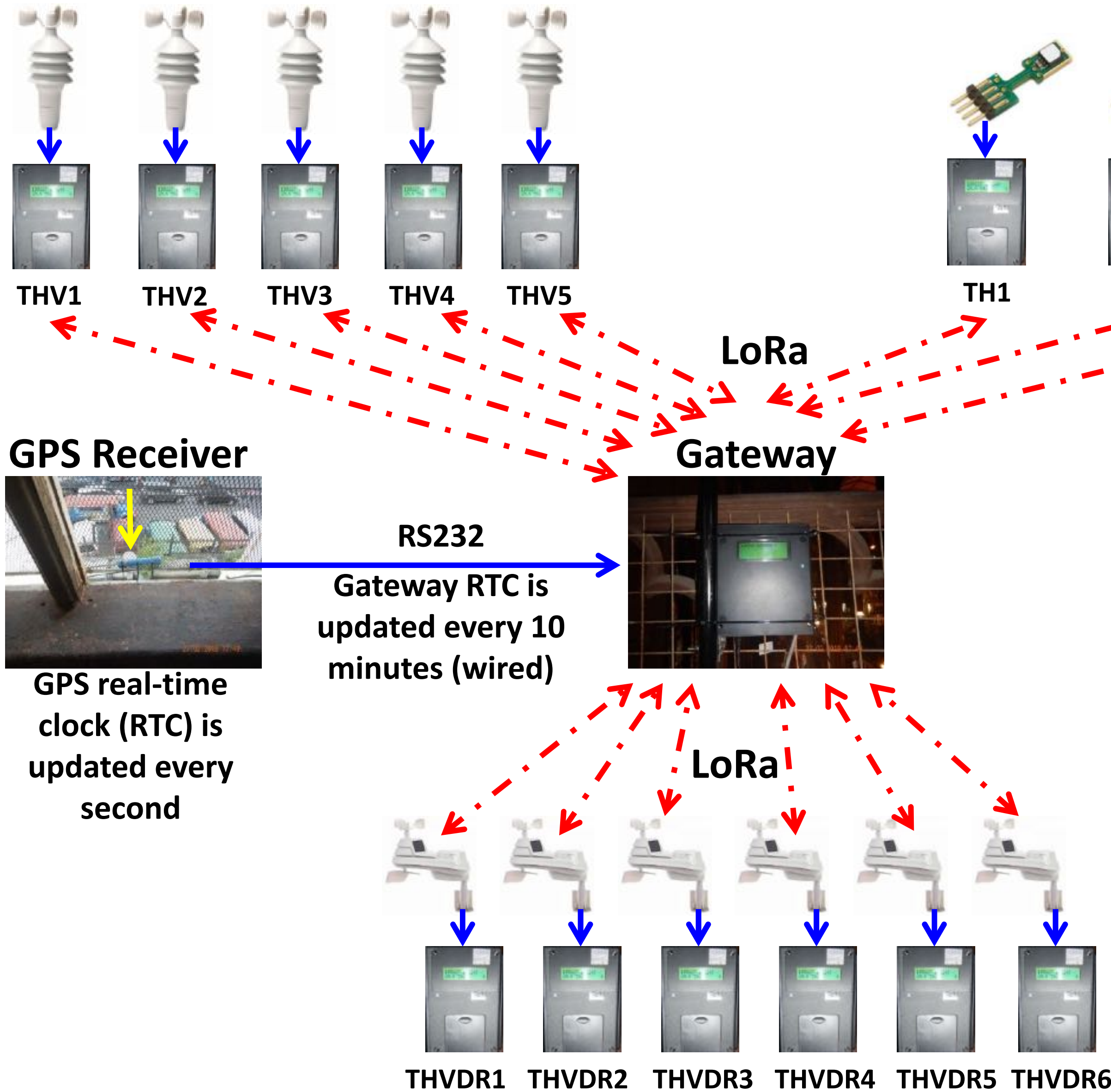
San Sebastian Basilica IoT Network Layout



SSB Environmental Monitoring System Operation

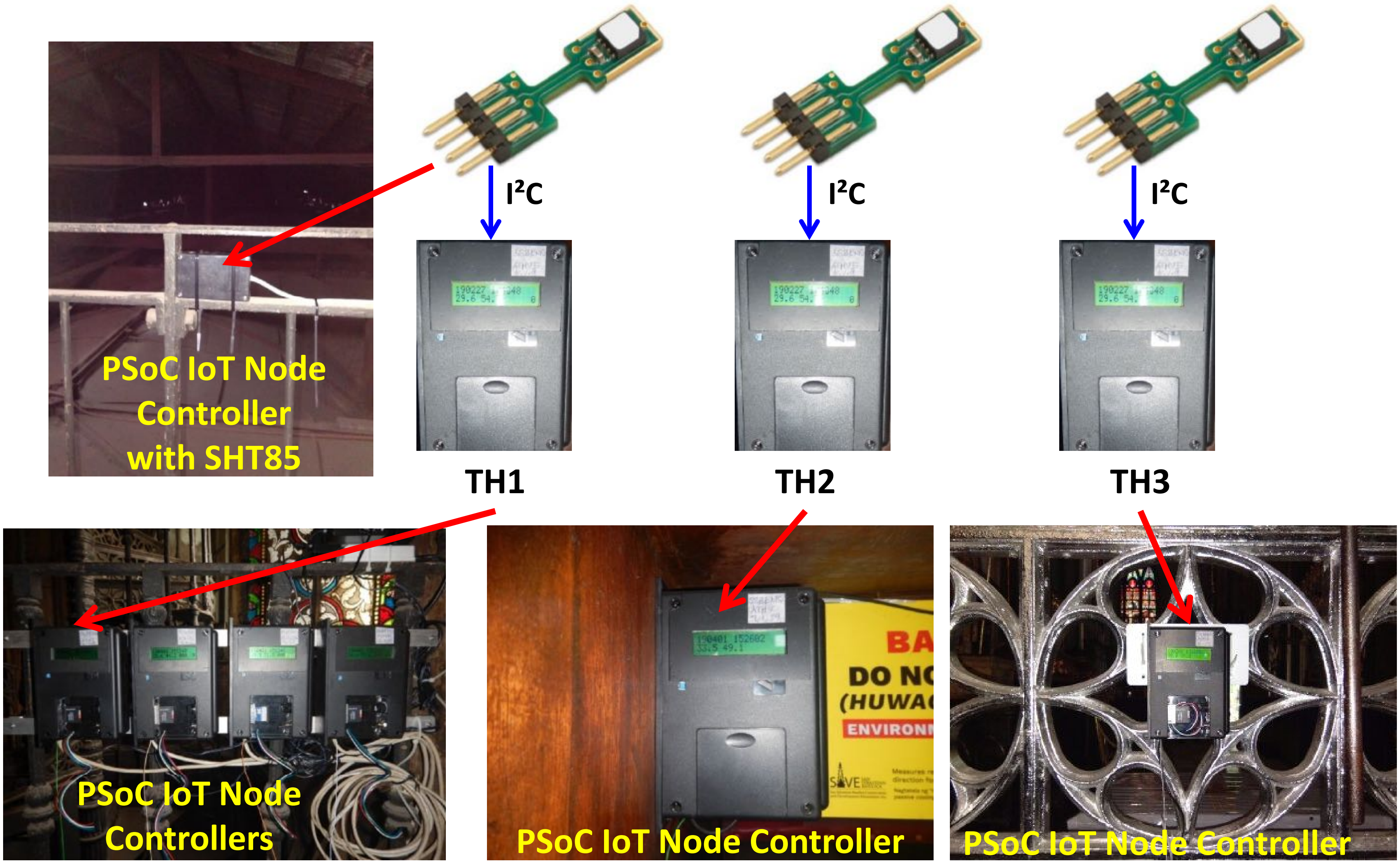


Synchronized Data Capture

1. GPS RTC is updated every second.
2. Gateway's RTC is updated every 10 minutes.
3. All stations' RTC are synchronized to the Gateway's RTC every minute via LoRa.
4. Simultaneously, all sensors' data are acquired and saved (logged) in the SD memory card every minute.
5. Every 10 minutes, Each station data is sent via LoRa to the gateway and immediately logged in the gateway's SD memo

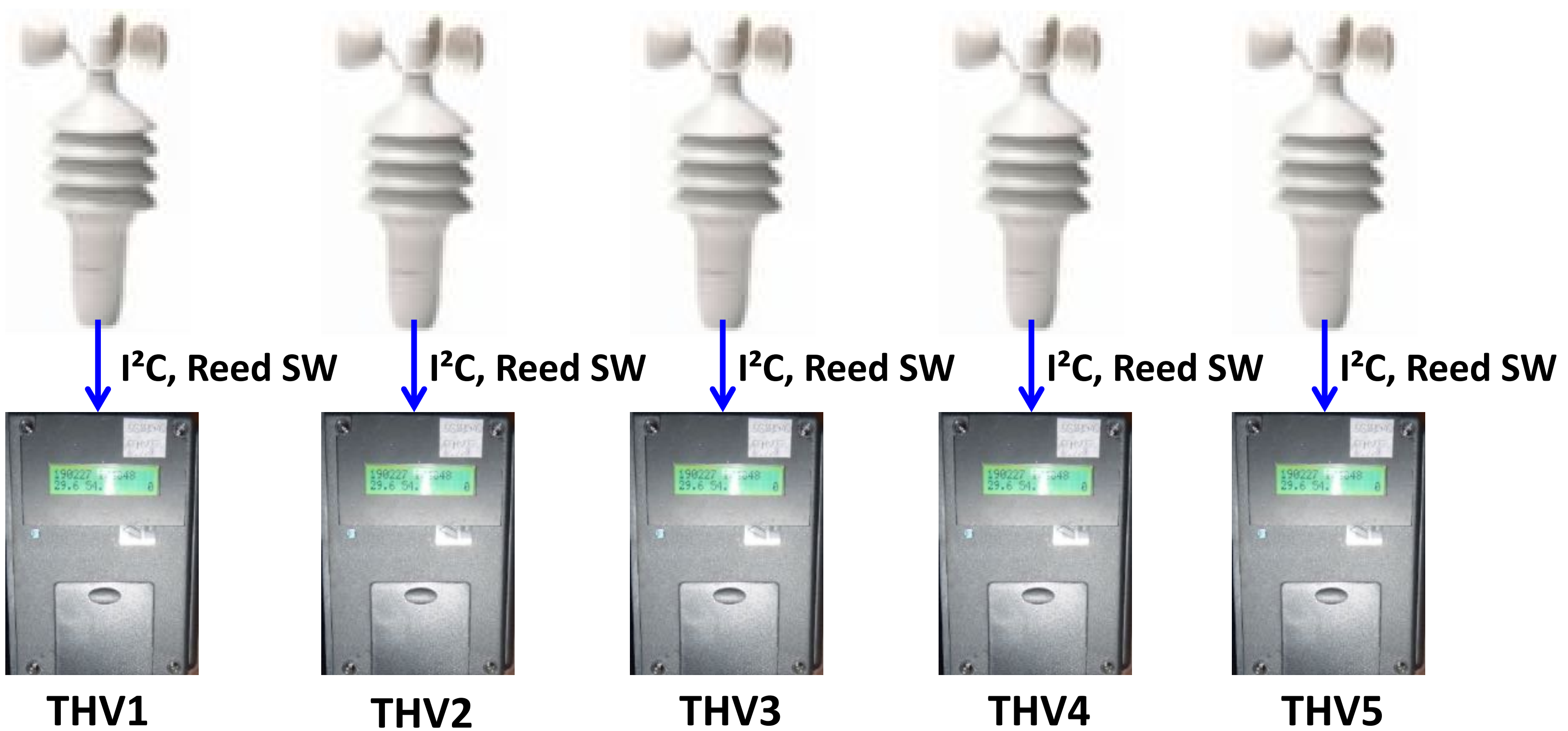
SSBEMS IoT Device Installation

Temperature and Humidity , SHT85, (THx) WSN Setup

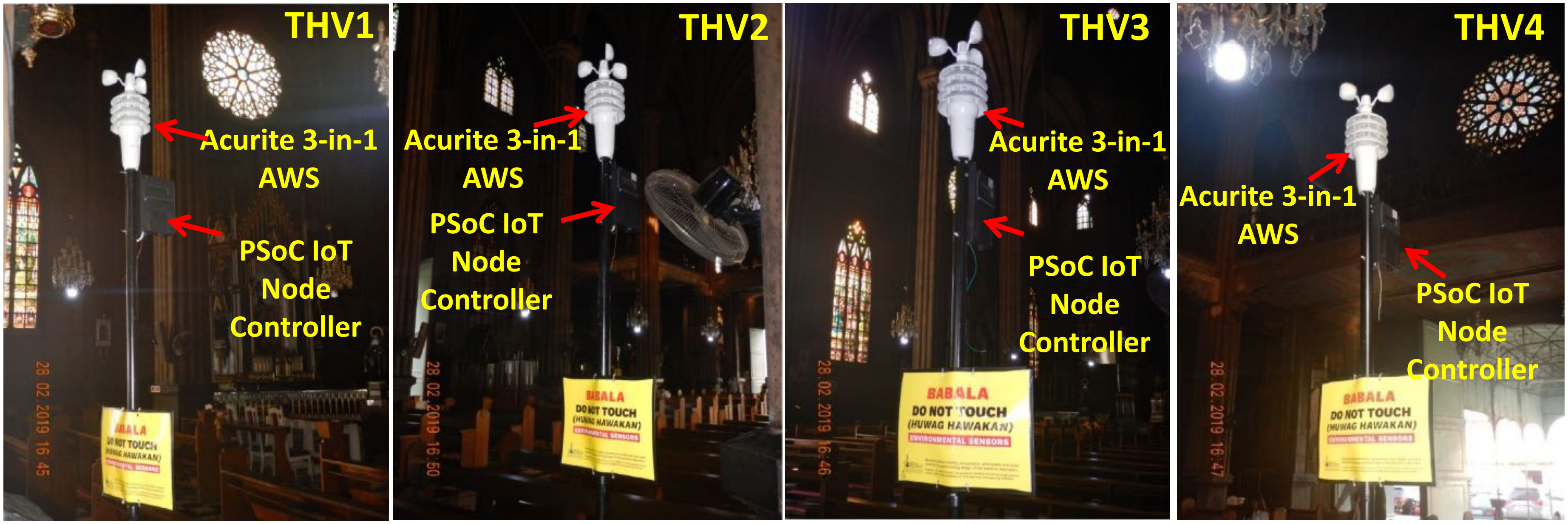


SSBEMS IoT to Sensor Connection Layout

Acurite 3-in-1 Weather Stations
WSN Setup:
Temperature, Humidity, wind Velocity (THVx)

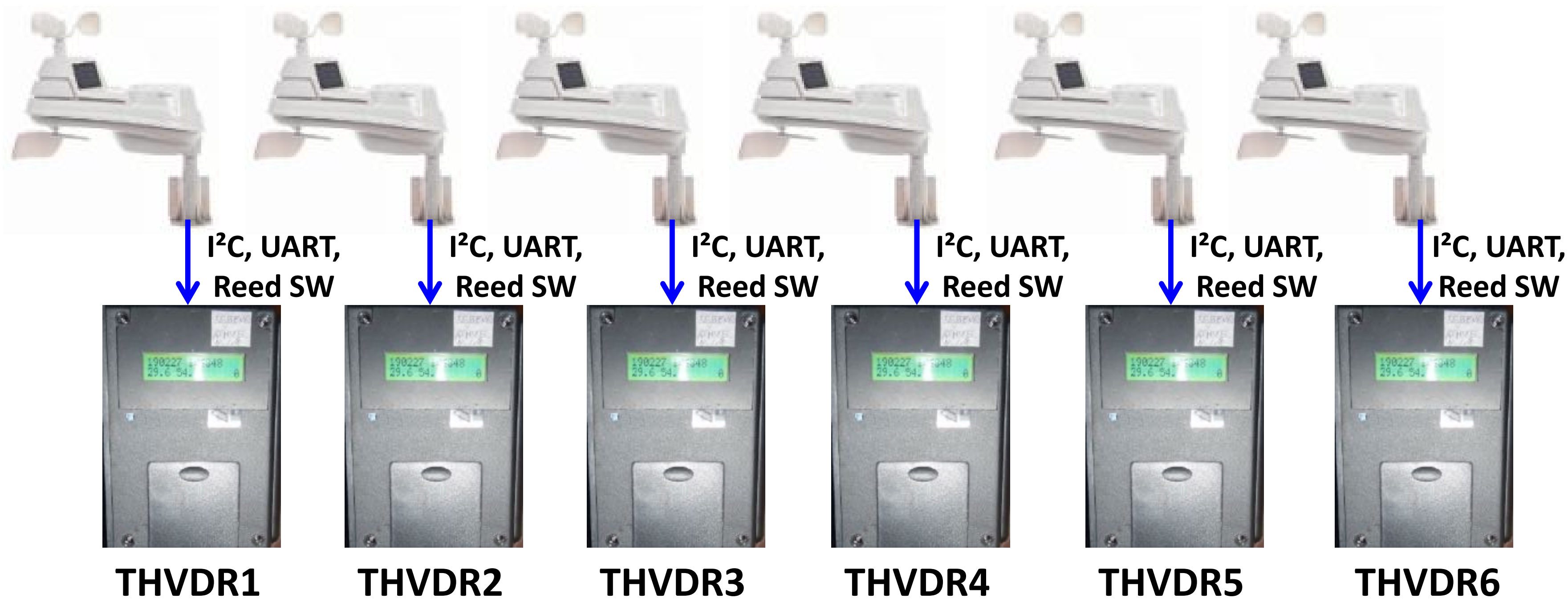


SSBEMS IoT Device Installation



SSBEMS IoT to Sensor Connection Layout

Acurite 5-in-1 Weather Stations
WSN Setup:
Temperature, Humidity, wind Velocity, wind Direction, Rainfall (THVDRx)



SSBEMS IoT Device Installation

THVDR1 – Basilica's East Side Door

THVDR2 – Basilica's West Side

SSBEMS IoT Device Installation

THVDR5 – Basilica's Front Door

THVDR3 – Basilica's East Side Front Door

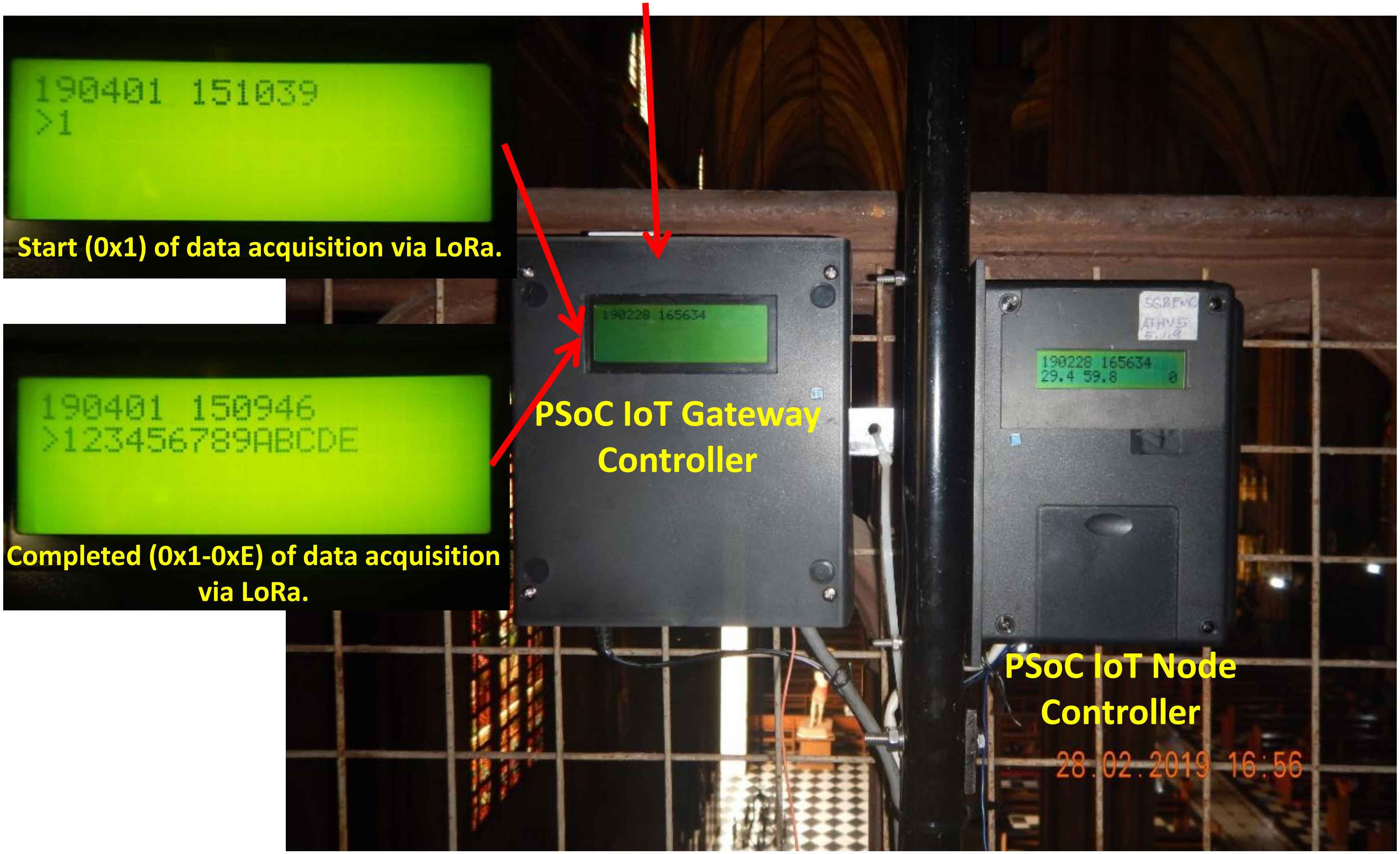
SSBEMS IoT Device Installation

THVDR4 – Basilica's Right Tower, 1 Level Below Bell Tower

THVDR6 – Basilica's Roof

IoT Gateway

PSoC Gateway – Choir Loft



Node Controller: Power, Data Display, and Data Logger

Date Time WindDirection

Temp Hum Rainfall WindSpeed

LCD Backlight Switch

2x16 LCD

Fuse Holder-small

12Vdc Power Switch

LoRa Antenna (433MHz)

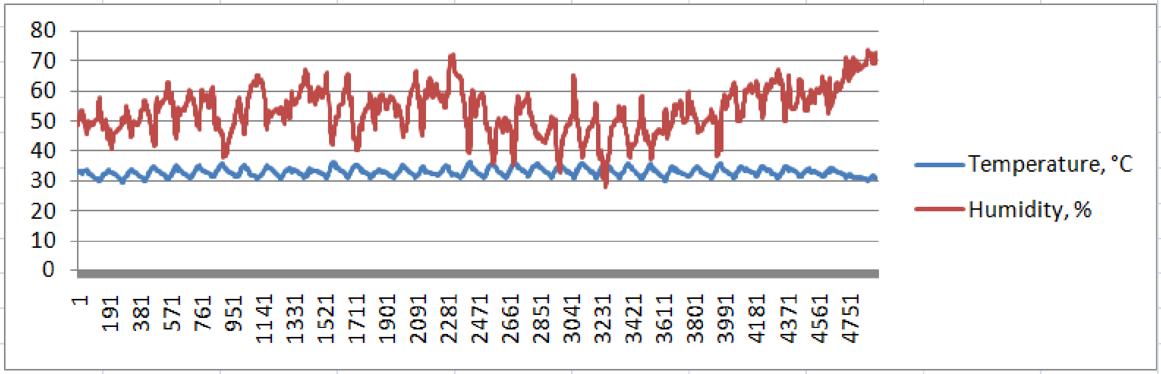
Sensor Data Communication Cable

SD/uSD Card Data Logger (4GB/8GB/16GB)

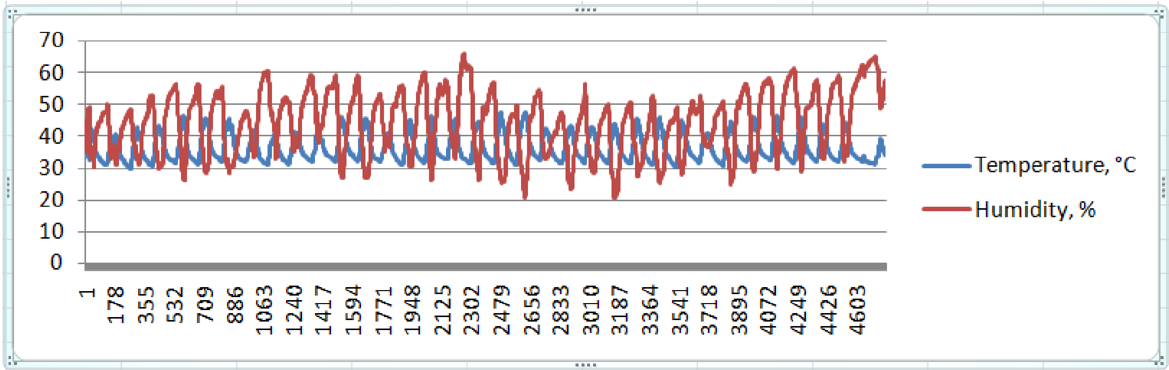
How to manually copy the CSV file: Recommended copy time is between 5th min to 8th min of the 10-min cycle.

1. Turn-off 12VDC Power Switch.
2. Take-out SD card from port.
3. Copy CSV file using your computer.
4. Re-insert SD card.
5. Turn-on 12VDC Power Switch.
6. Station should operate normally.

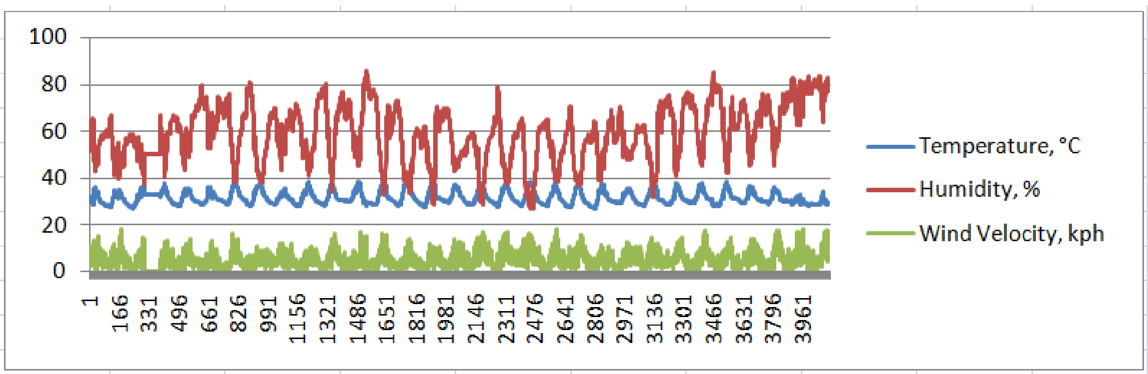
Actual Data Charts, March 29 to May 7, 2019



TH3 – Altar, Left Side

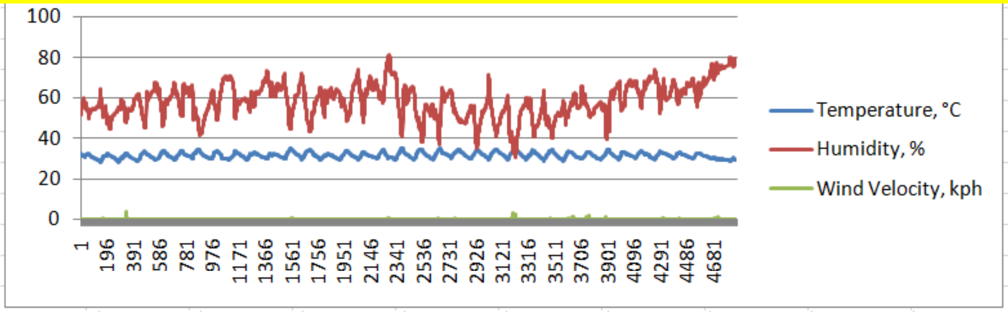


TH1 – Attic

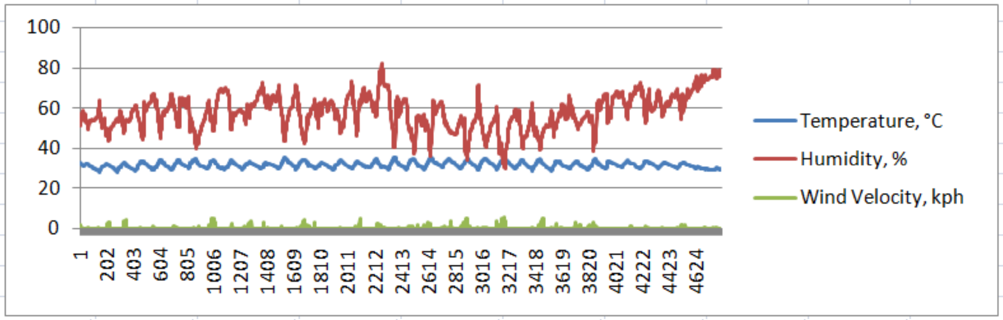


THVDR6 – Basilica's Roof

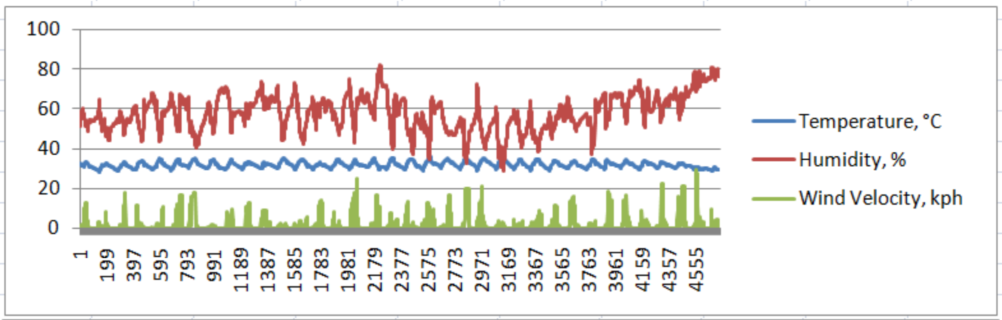
Actual Data Charts, March 29 to May 7, 2019



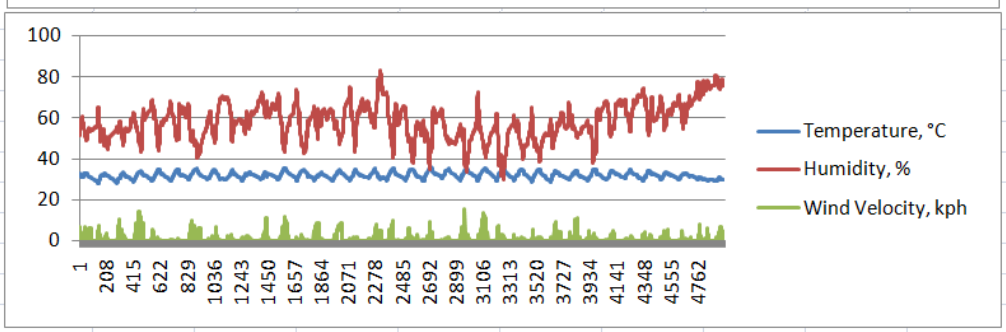
THV1 – Pew



THV2 – Pew



THV3 – Pew



THV4 – Pew

Next IoT Project: Structural Health Monitoring (SHM) – for structural integrity monitoring

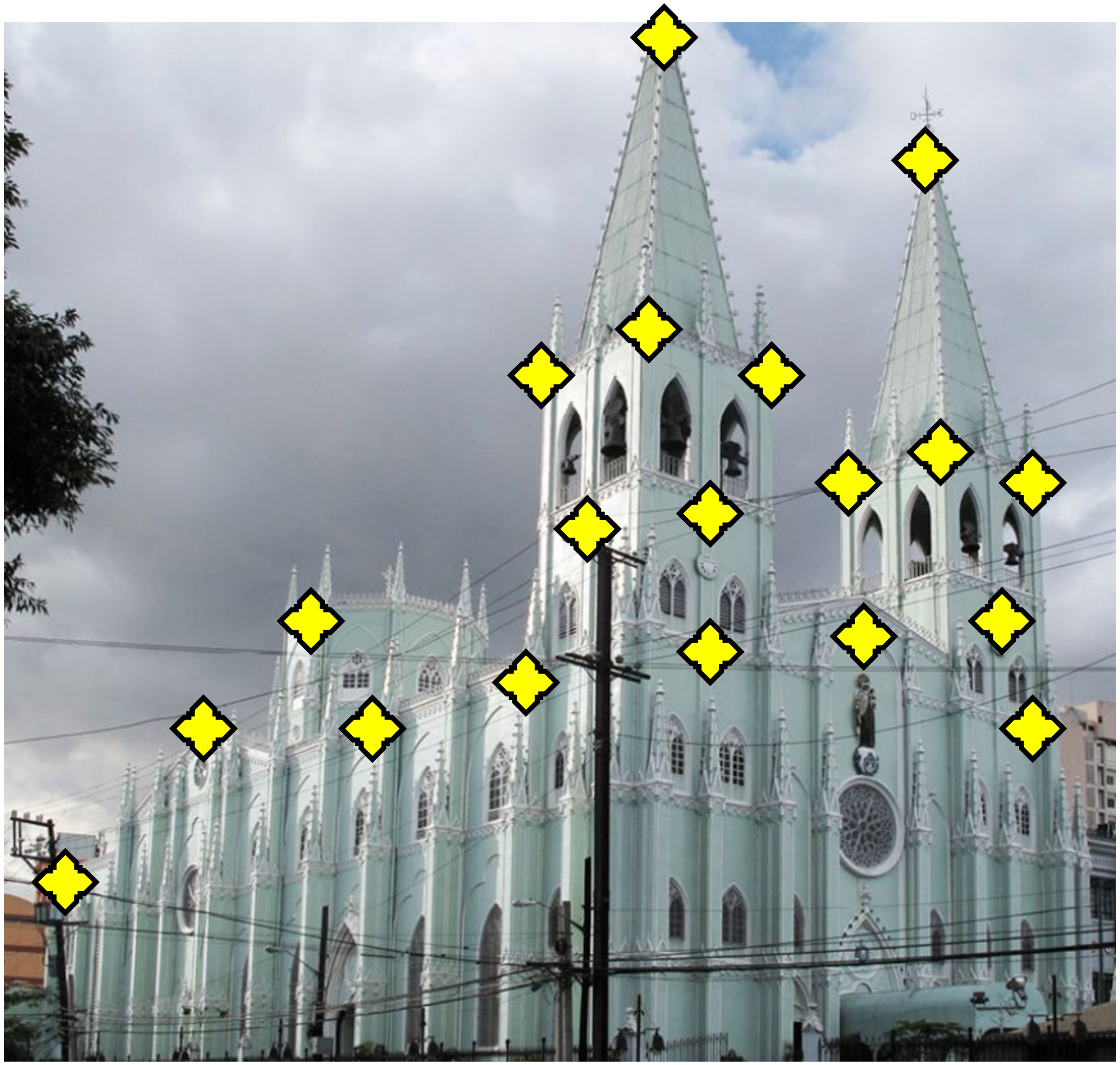
Project Objectives:

1. To provide continuous real-time (24-7) monitoring of parts (walls, decorations, etc) of the church which are susceptible to abrupt or creeping movements (inclination or vibration) due to decaying material joints, seismic ground movements, and massive vibrations from nearby sources or construction.

2. To automatically inform (via internet, SMS, or localized light indicators) the conservation team if church's parts (walls, decorations, etc) are in critical positions, and if there is impending danger of falling-off from its point of attachment. This would help prevent accidents due to falling debris.

GTEK ENTERPRISE

Structural Health Monitoring (SHM), Proposed Dec 2019



IoT Solution:

Solar-battery powered WSN using PSoC, LoRa, and precision MEMS sensors.

To collect real-time data from:

1. XYZ Inclination
2. XYZ Vibration

To be utilized by structural and metallurgical engineers.

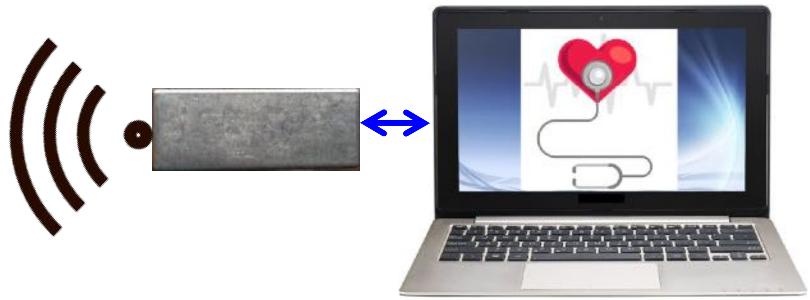
ASEAN IVO 2022 Research Project 03:

P2EI-WEALTH (Physiological and Psychological Edge Intelligence WEArable LoRa HealTH) System for Remote Indigenous Community and Disaster Recovery Operations

Wearable IoT+ML Device

LoRa

Remote Data Center



Provides Data to Data Center about:
- Physiological: HR, Sp02, ECG, Temp
- Psychological: Galvanic Skin Response, GSR
- Motion: Walking, Running, Idle, Free-fall, Single/Double Tap
- Environmental : Temp, Humidity, Air-Quality, and Baro. Pressure
- Location: GPS Location Coordinates, Date and Time

=

Benefits: This real-time remote patient monitoring method will provide medical doctors, who are remotely located in the city, the needed medical data while a patient is still in the danger zone. This timely information would be helpful in assessing the health conditions and the preparation for the proper medical treatment for a victim.

https://www.nict.go.jp/en/asean_ivo/ASEAN_IVO_2022_Project03.html

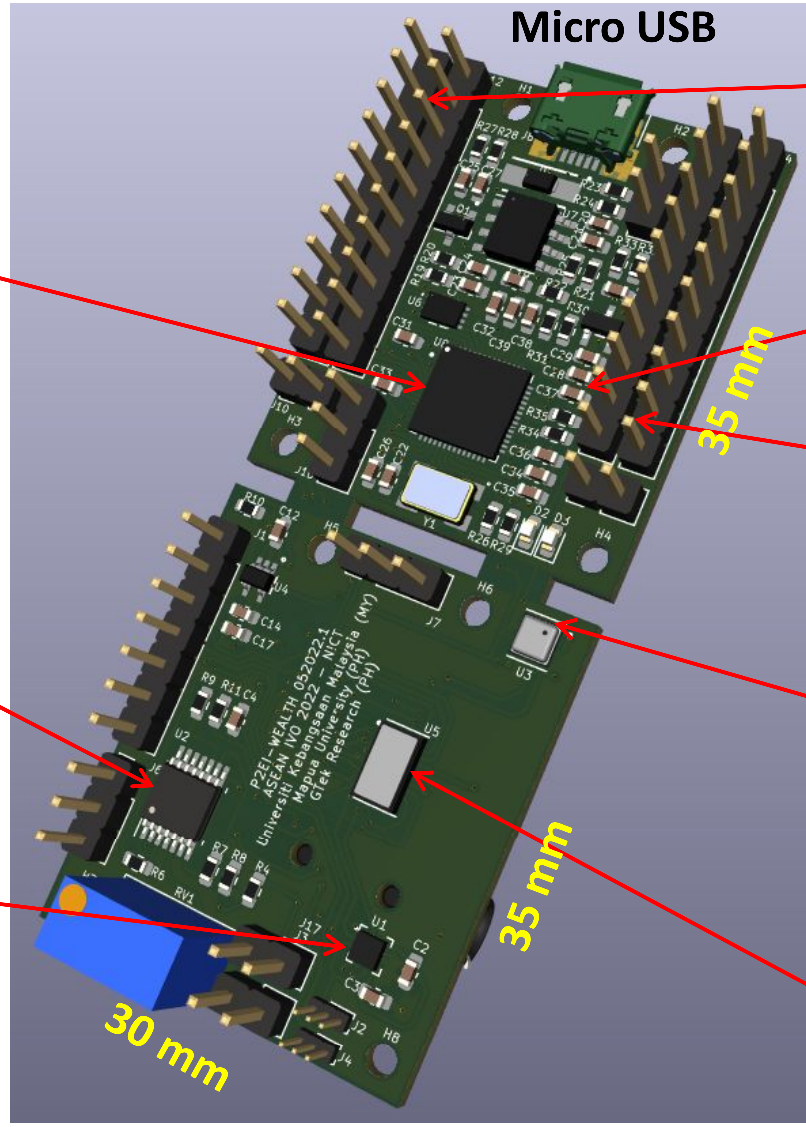
GTEK ENTERPRISE

P2EI-WEALTH Wearable IoT + TinyML Device

MCU:
Dual Core ARM Cortex-M0+ @ 133MHz. Edge Impulse supported MCU for TinyML

GSR Sensor

Motion Sensor: Walking, Running, Idle, Free-fall



LoRa: 400/800/900 MHz

OLED 128x64

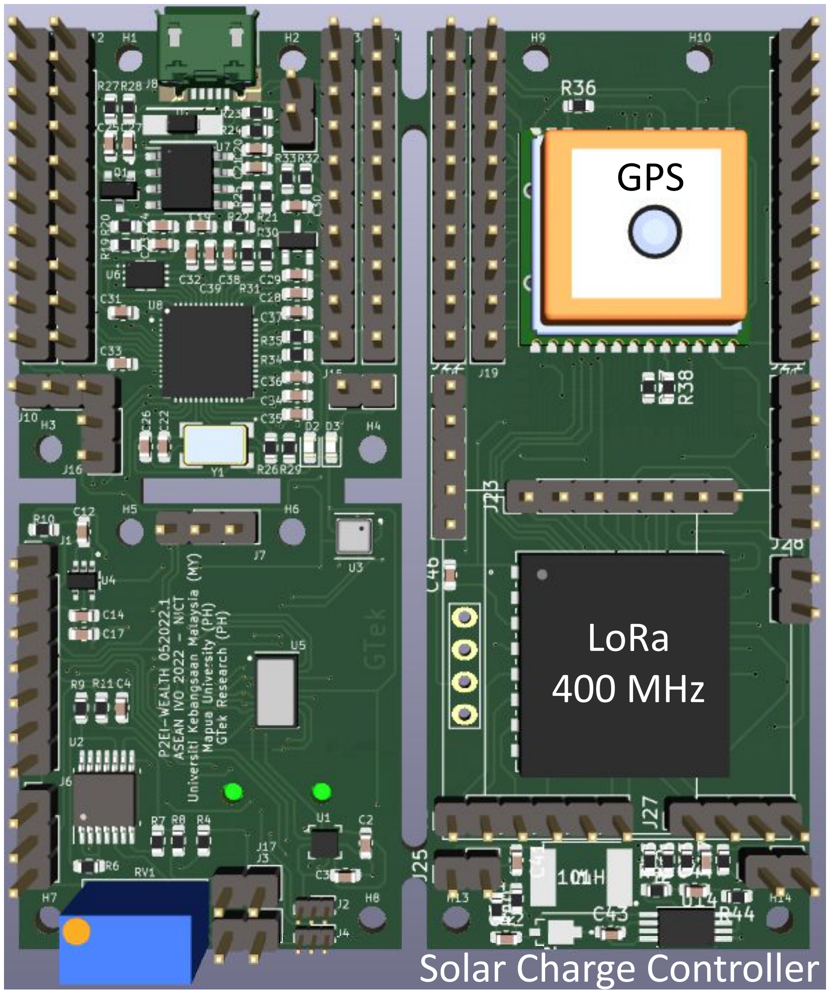
GPS Receiver

Environment Sensors: Air Quality, Humidity, Pressure, and Temperature

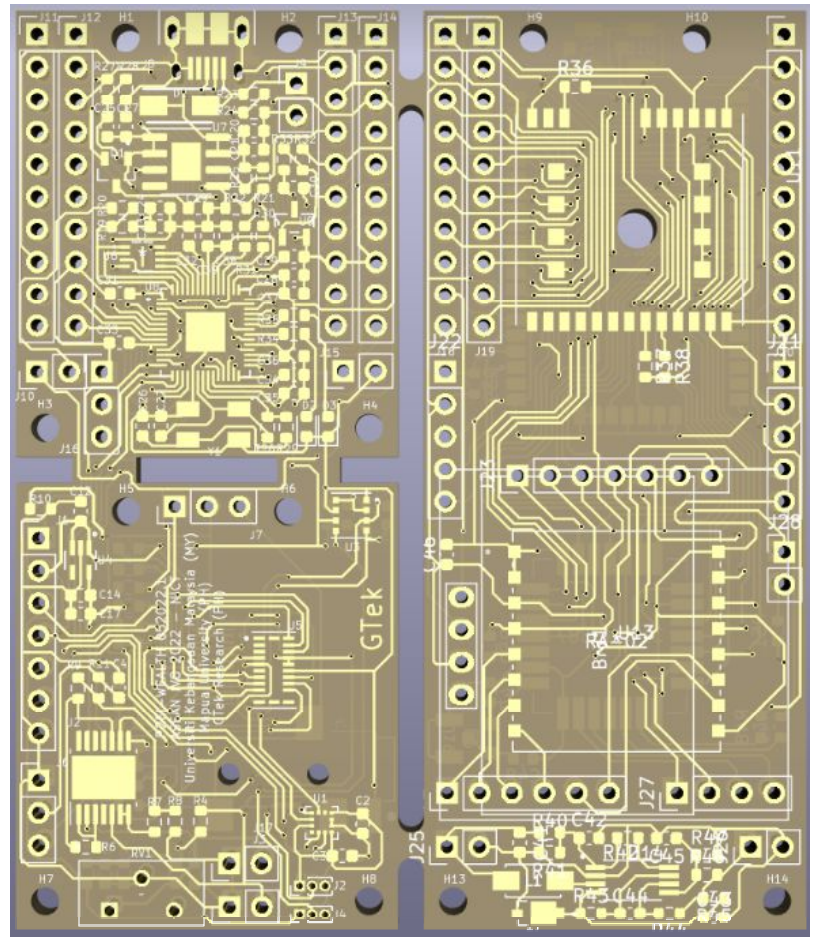
Biosensor: ECG, SpO2, Heart-Rate

P2EI-WEALTH Wearable IoT + TinyML Device

MCU + Sensors - Front **Comm - Front**

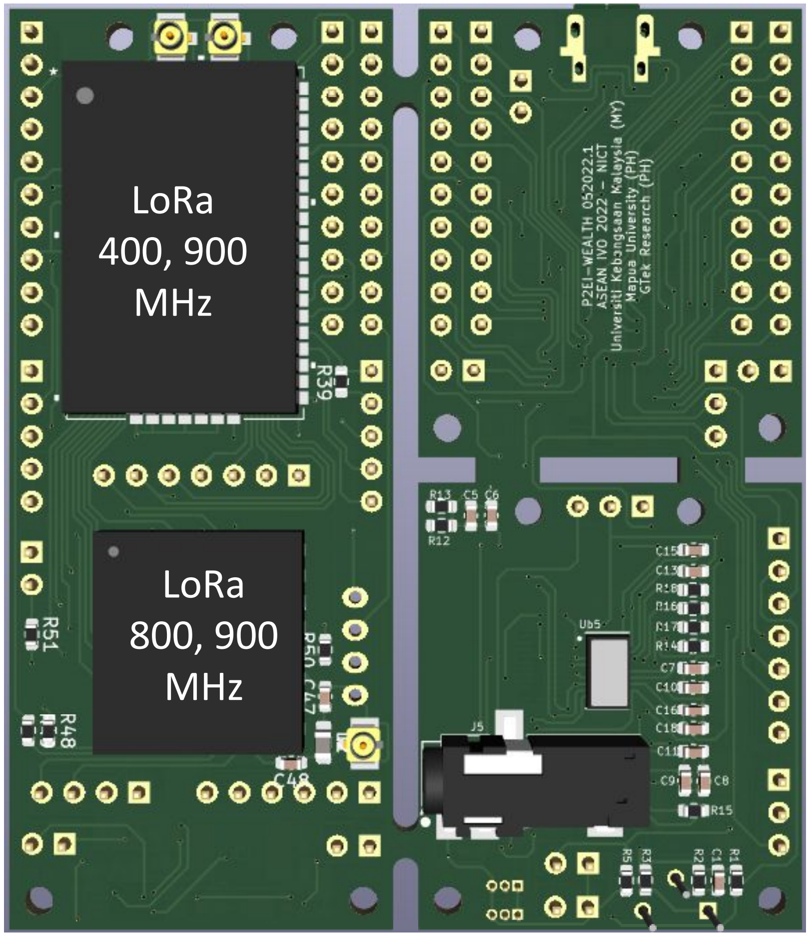


Front PCB Layout

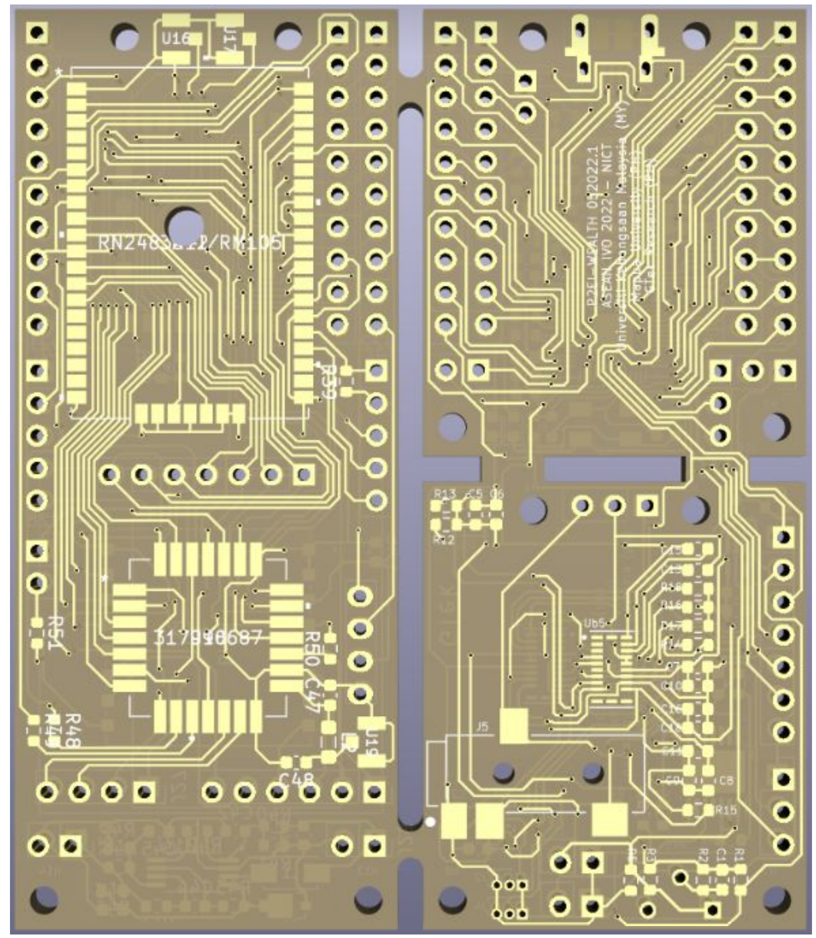


P2EI-WEALTH Wearable IoT + TinyML Device

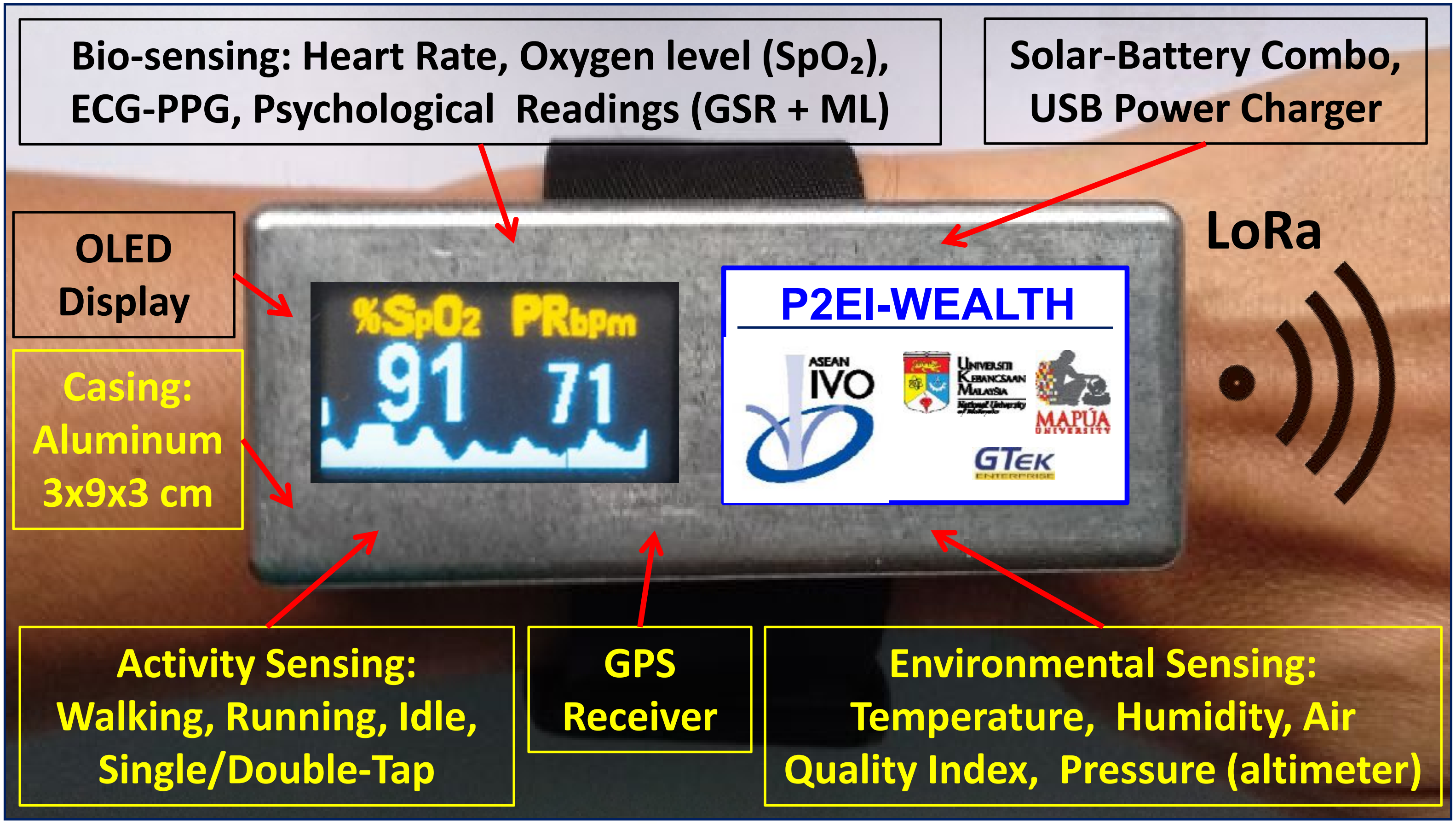
Comm - Back **MCU + Sensors - Back**



Back PCB Layout

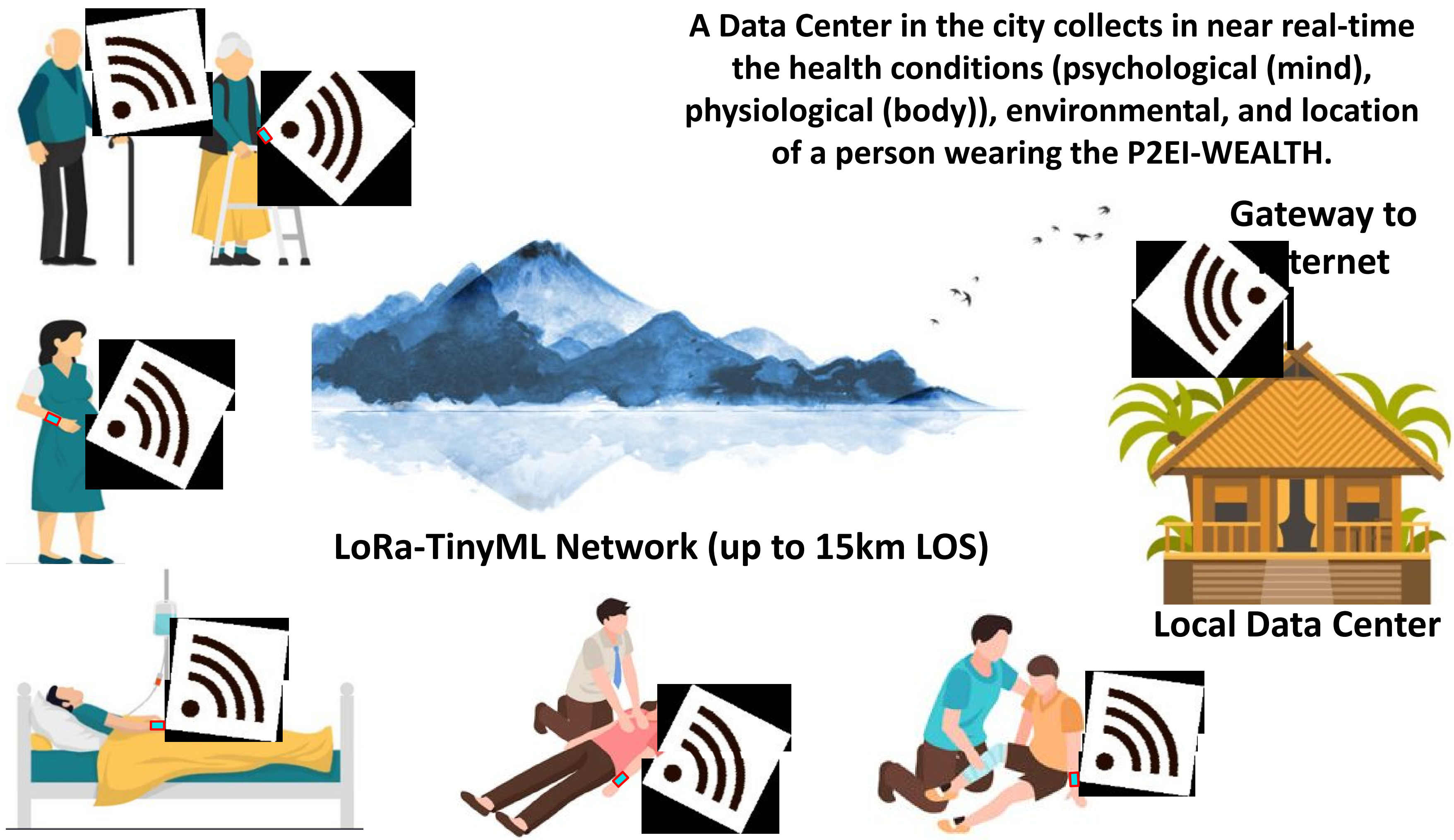


P2EI-WEALTH Wearable IoT + TinyML Device



P2EI-WEALTH Remote Indigenous Community Operations at Chini Lake

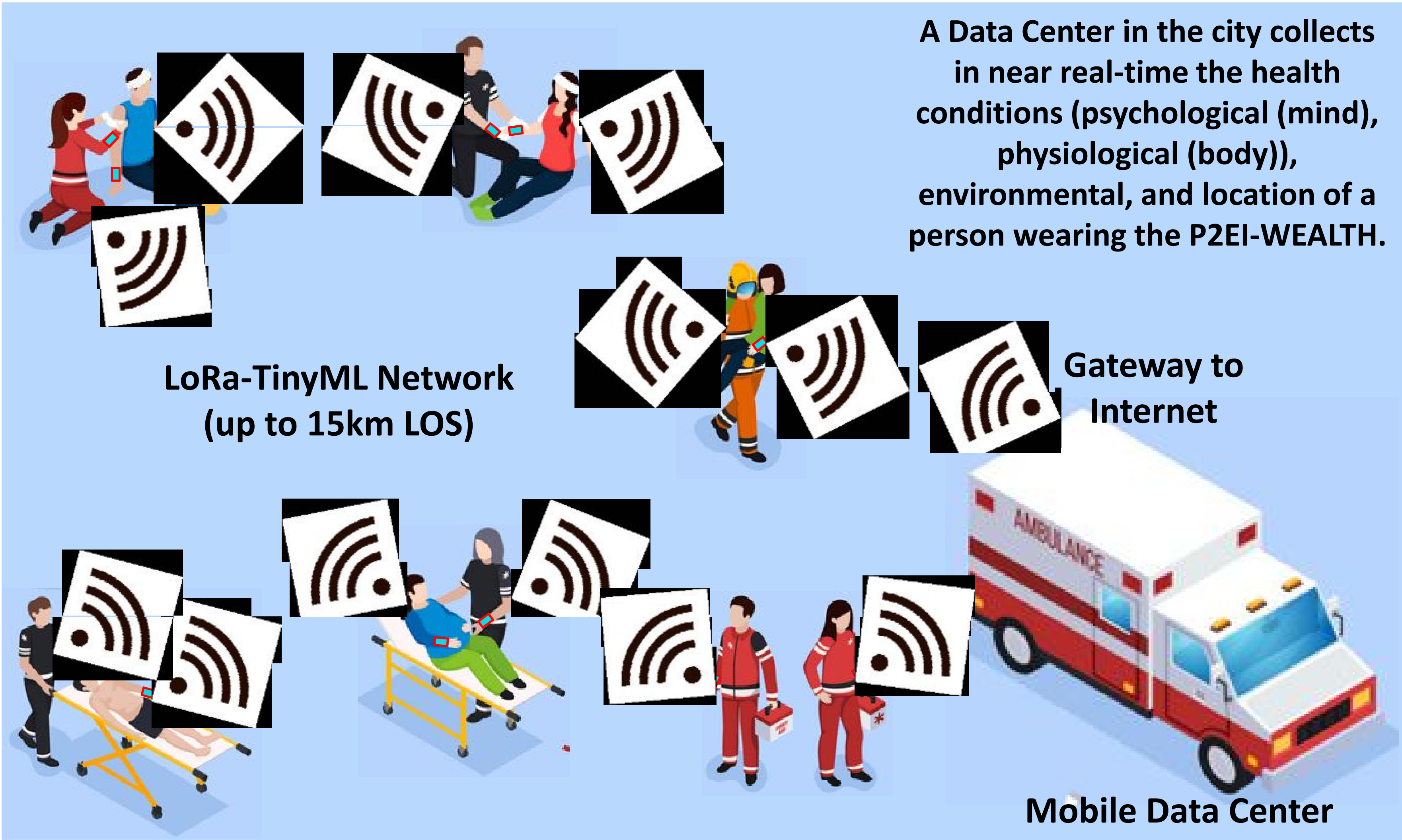
Elderly, Pregnant, Sick, and Injured Patients Benefit from the P2EI-WEALTH Solution



GTEK ENTERPRISE

P2EI-WEALTH Remote Disaster Recovery Operations

Disaster Victims and Emergency Rescuers Benefit from the P2EI-WEALTH Solution



Thank you ICTP friends.
Stay safe.