Low-Cost GNSS Receiver System for Multi-Purpose Applications

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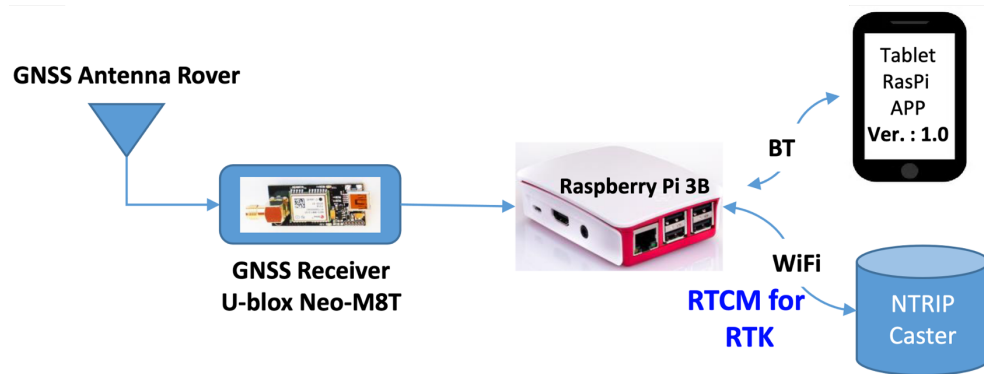Center for Spatial Information Science (CSIS), The University of Tokyo

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Low Cost GNSS System: Introduction

Receiver Type including Antenna	Price	Observation	Raw Data	Timing	Other
Single Frequency	<$100	DGPS	Code-Phase only		
Single Frequency	< $300	DGPS, RTK (Short BL)	Code and Carrier Phase	1PPS Out	NAV Data Bits Useful for NMA
Dual Frequency	< $500	DGPS, RTK	Code and Carrier Phase	1PPS Out	NAV Data Bits Useful for NMA
Triple Frequency	< $1000	DGPS, RTK	Code and Carrier Phase	1PPS Out	NAV Data Bits Useful for NMA

Low Cost GNSS Prototype: RtkPi (2016)

- Single Frequency GNSS Receiver for short baseline RTK

- Raspberry Pi running RTKLIB 2.4.3

- USB cellular modem for internet

- No Enclosure

- High power consumption

- Some assembly required to set up

GNSS Antenna Rover

GNSS Receiver
U-blox Neo-M8T

Raspberry Pi 3B

BT

Tablet
RasPi
APP
Ver. : 1.0
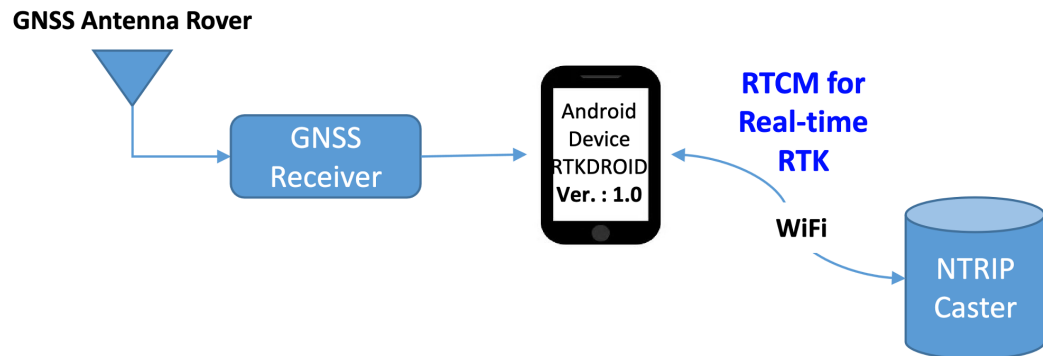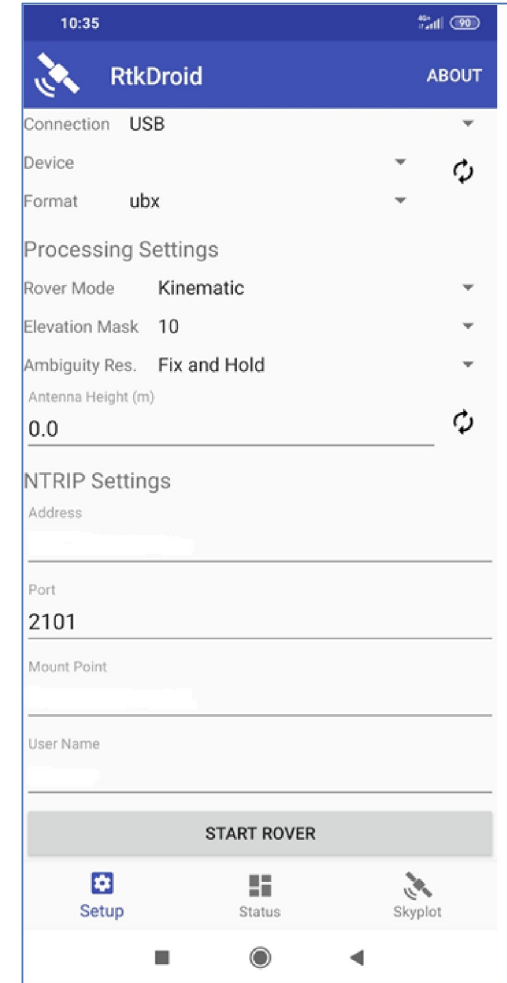
WiFi

RTCM for
RTK

NTRIP
Caster

RtkDroid App for Android (2018)

- Single frequency receiver connected to Android using USB-OTG
- RTKLIB running on Android

- Requires Android smartphone to be running at all times
- Receiver powered by smartphone battery
- Requires wired connection

GNSS Receiver Module

# Low Cost GNSS Receiver: Cost of Operation

- Requires a PC, a single board computer, or Android smartphone
  - Expensive
  - High power consumption
  - Needs some assembly every time
  - Not easy to use in field conditions

- Requires an RTK base station if nearby CORS station is not available
  - PC required setting up a low-cost GNSS as base station

- Cost of training GNSS receiver operators

- Cost of maintenance, replacement parts, software licenses

Improved Multi-Purpose Low-cost System
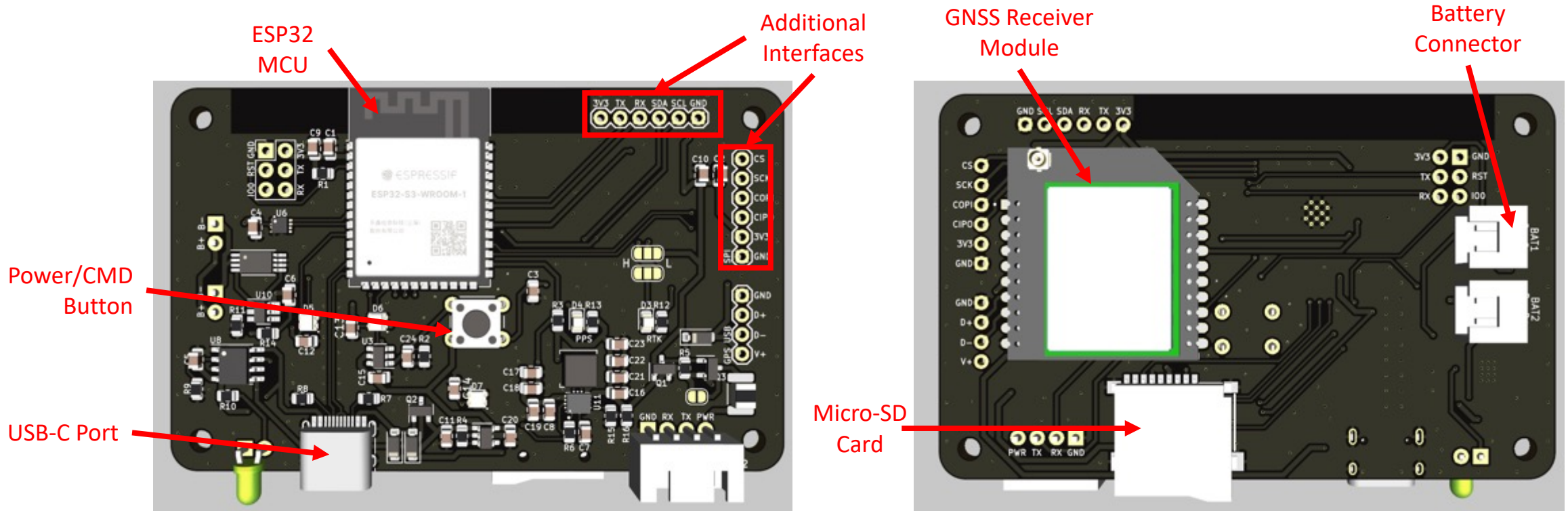
Requirements:

- Simple unattended data-logging: one button click to start/stop

- RTK Base and Rover configuration using smartphone

- Connect to both Android and iOS devices to improve on-device location with Bluetooth LE

- Wi-Fi connectivity for base station operation and log file uploads

- Low power consumption, in-built battery management

Multi-Purpose Low-Cost GNSS System Design
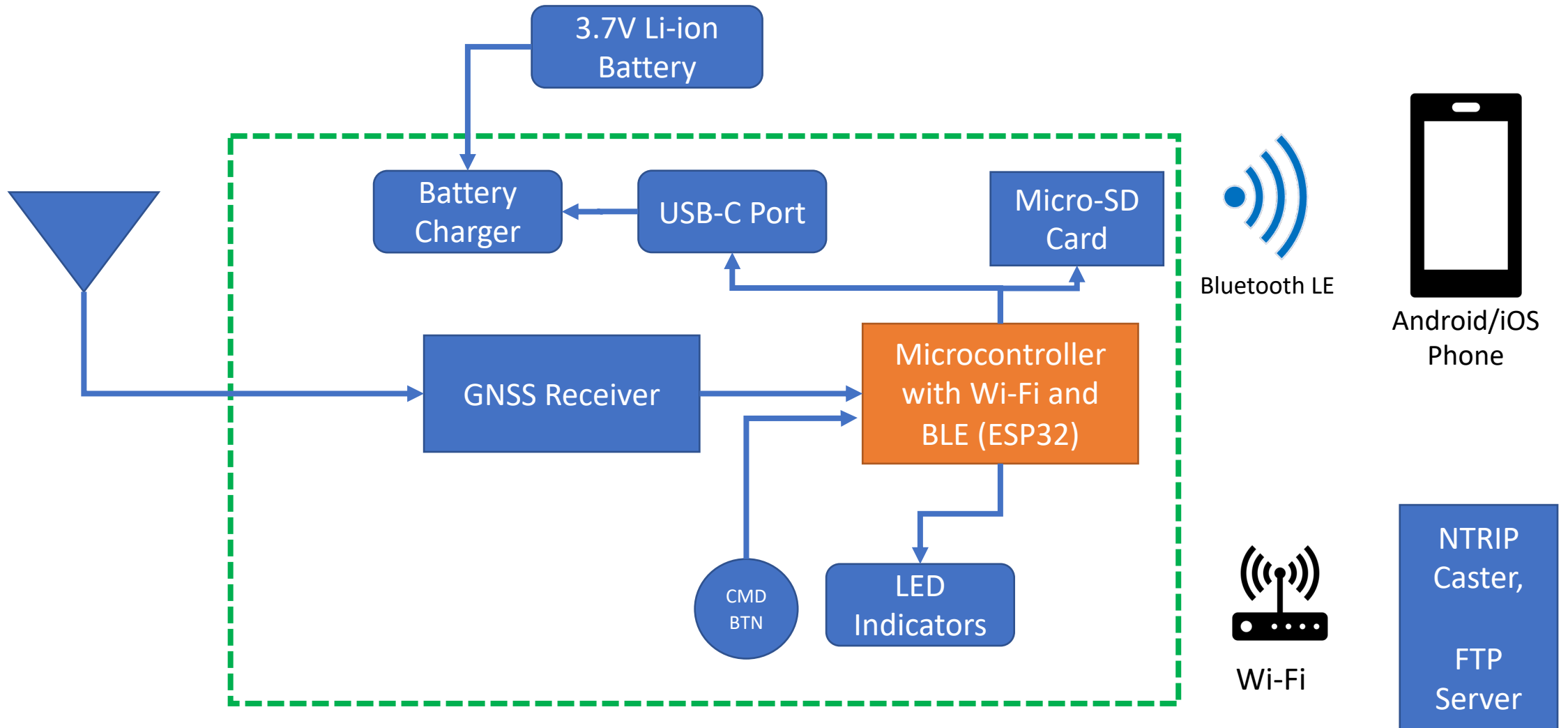
# Multi-Purpose Low-Cost GNSS System Design

- Single PCB Design

- ESP32 Microcontroller: <u>Programmable using Arduino</u>

- Additional communication interfaces for expandability
  - Connect IMU, radio links or other sensors

ESP32 MCU

Additional Interfaces

GNSS Receiver Module

Battery Connector

Power/CMD Button

USB-C Port

Micro-SD Card

Multi-Purpose Low-Cost GNSS System Design

Uses XBee 20-pin form factor for GNSS receiver connection
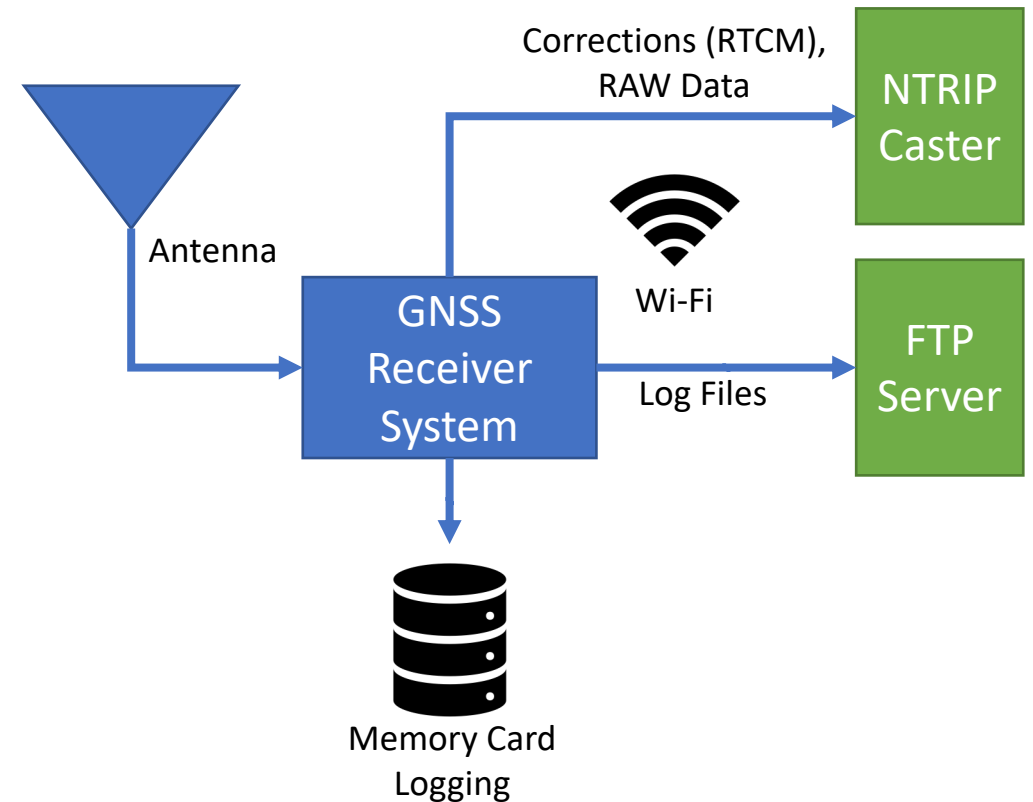Can use same board with dual or triple frequency GNSS receivers
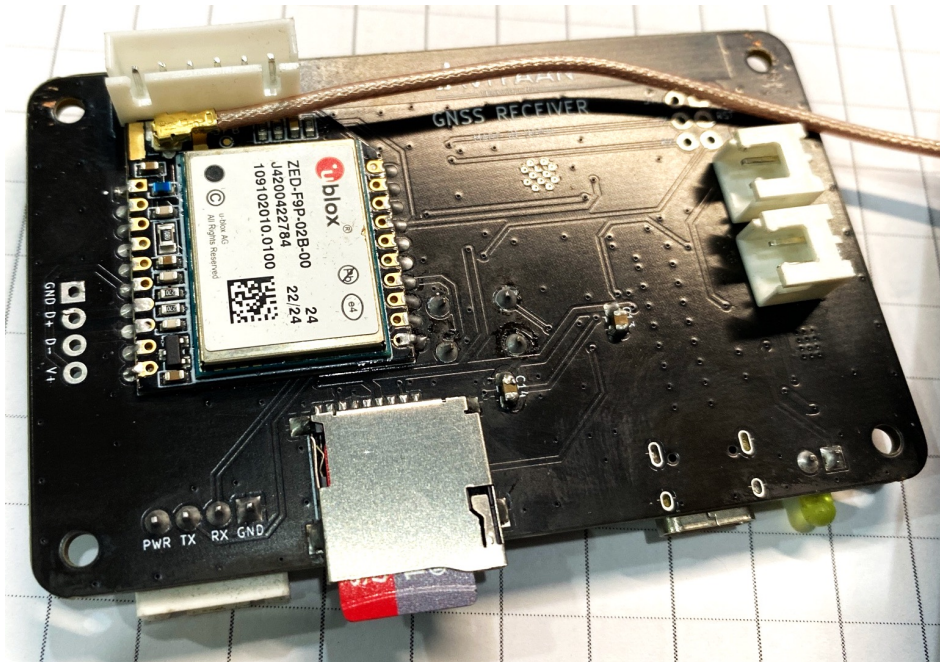
GNSS Receiver Board with Dual-Frequency (L1+L2)
Receiver

GNSS Receiver Board Upgraded with Triple-Frequency
(L1+L2+L5) Receiver

Low-Cost GNSS Device with External Antenna

- Useful for static applications
  - Low-Cost CORS
  - Space Weather Monitoring
 - Crustal movement and land subsidence monitoring

Low-Cost GNSS System for Surveying (RTK/ Data Logging)

- Everything in one enclosure, no user assembly required

- Press power button twice to log data

- Connect to smartphone using Bluetooth LE and use data collector apps for RTK surveying.

- Battery lasts over 24 hours with L1/L2 dual-frequency receiver. Charge using USB-C.

- Base/Rover setting using Smartphone app

Battery Pack

Antenna

3D Printed Enclosure
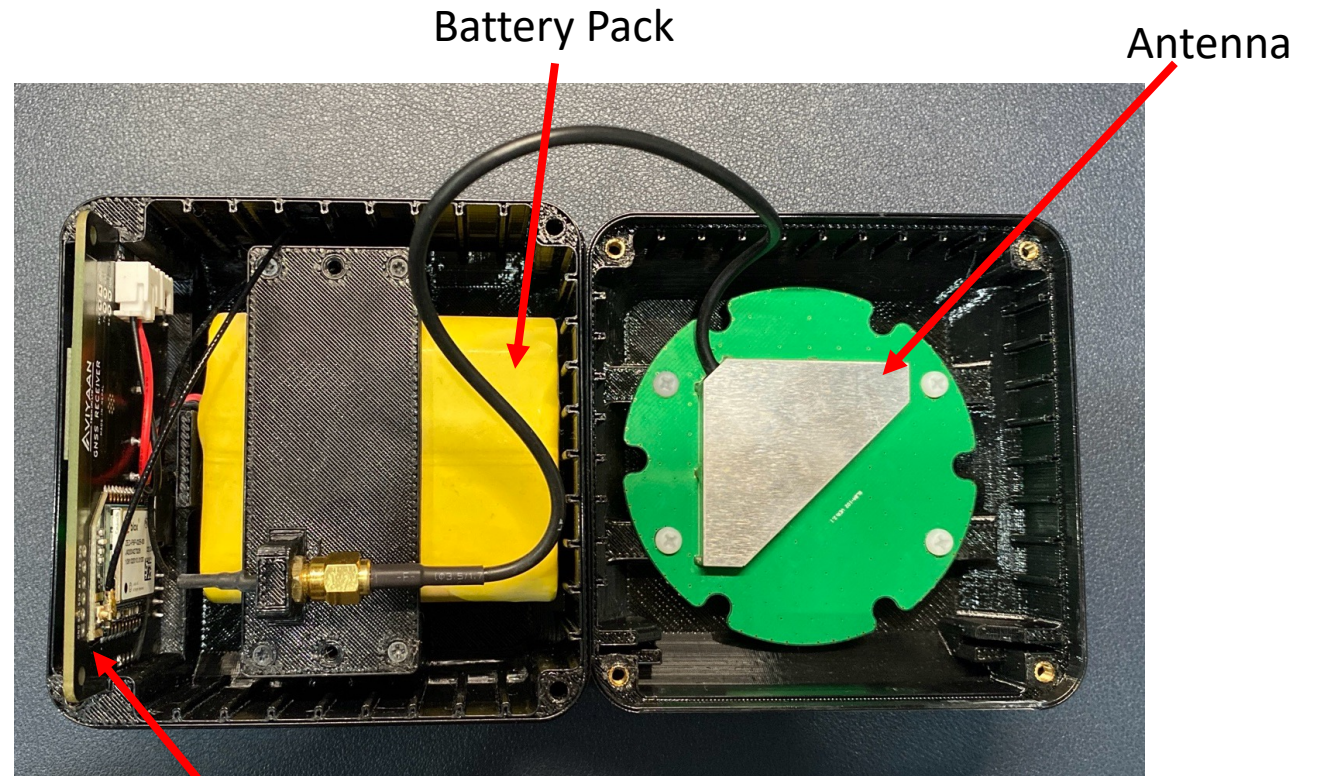
GNSS Receiver Board

Low Cost GNSS System: RTK Applications

- Most dual frequency GNSS modules have built-in RTK capability
  - Use a smartphone app with NTRIP client
  - Implement NTRIP Client in the MCU firmware

- For receiver modules without RTK
  - Use the RtkDroid app with Bluetooth connection

- Low-Cost GNSS as RTK Base Station
  - NTRIP V1 Server implemented as Arduino firmware
  - Can stream data to remote NTRIP caster over Wi-Fi
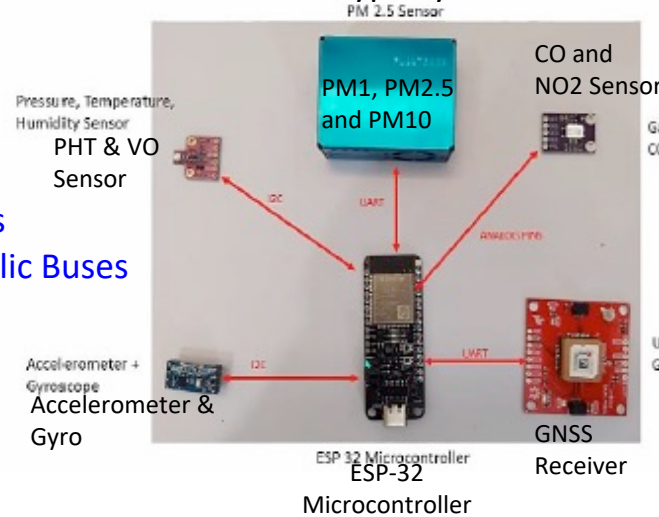 - Receiver module configured to output RTCM V3

Pilot Projects: Dynamic Air Quality Monitoring

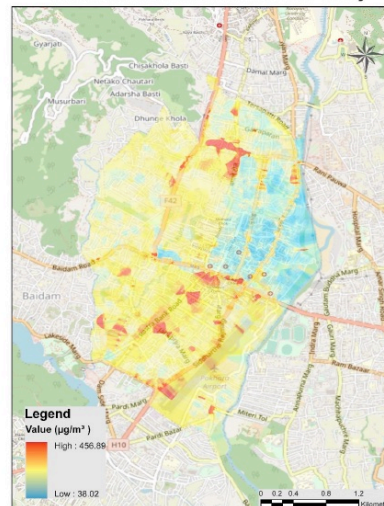Before Lockdown Period

During Lockdown Period

Photo Sources: https://www.nepalitimes.com/here-now/nepals-smoky-mountains/?fbclid=IwAR31xbeCKSSj9_gN0AU7BKMquQAzTg0Z6J-LUTmtsZu9o7o9ozsddu8Z5Vo

- Monitor City Air Quality
- Dynamic and Real-Time
- Use Low-Cost Sensor Systems
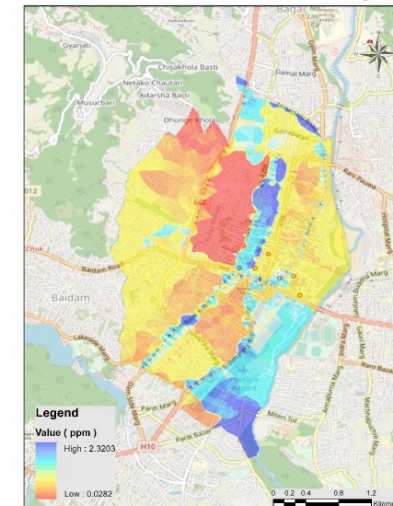- Implement the Sensor in Public Buses
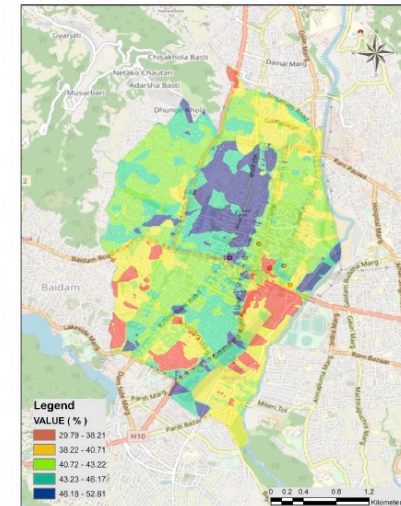
Prototype System

PM 2.5 Sensor
PM1, PM2.5 and PM10
CO and NO2 Sensor
Gas Sensor CO + NO2
Pressure, Temperature, Humidity Sensor
PHT & VO Sensor
Accelerometer + Gyroscope
Accelerometer & Gyro
ESP 32 Microcontroller
ESP-32 Microcontroller
U-blox S GNSS
GNSS Receiver

PM2.5 Concentration in Pokhara Valley

Legend
Value (µg/m³)
High : 456.89
Low : 38.02

NO2 Concentration in Pokhara Valley

Legend
Value (ppm)
High : 2.3203
Low : 0.0282

Humidity Distribution Map of Pokhara Valley

Legend
VALUE (%)
29.79 - 38.21
38.22 - 40.71
40.72 - 43.22
43.23 - 46.17
46.18 - 52.61

System Cost Breakdown

- GNSS Receiver Board Hardware: $100

- GNSS Receiver Module
  - Dual Frequency (L1+L2): $200
  - Triple Frequency (L1+L2+L5): $700

- Antenna
  - L1+L2: $100
  - L1+L2+L5: $200

- Battery and power supply: $50

- 3D Printed Enclosure: $50

- Software: **FREE**
  - RTKLIB
  - SW Maps

Dual Frequency GNSS system can be built for around $500

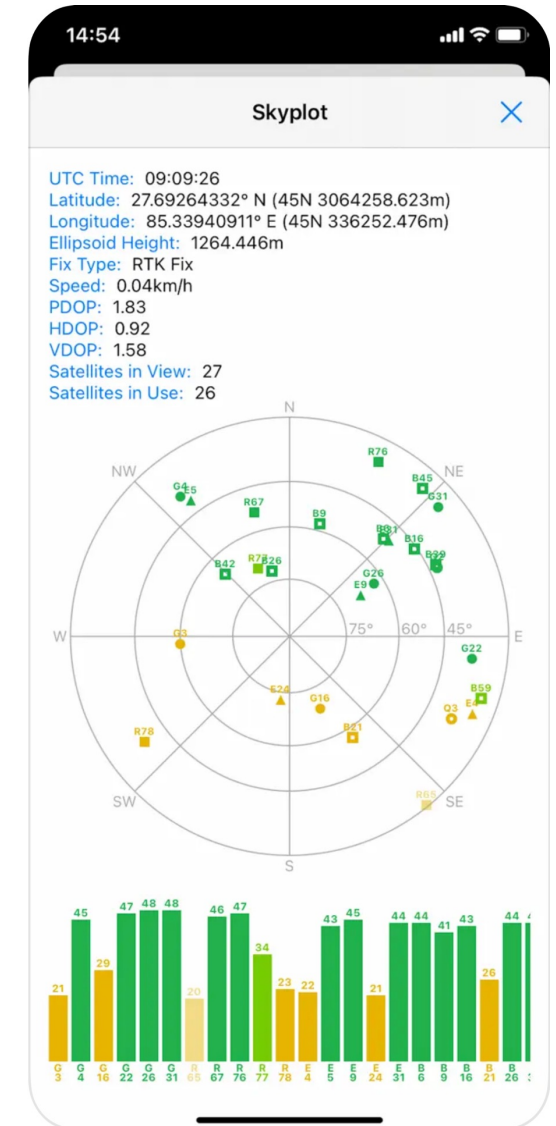*Note: Approximate prices in 2023, excluding taxes and shipping fees.*

Low-Cost GNSS System: RTK Applications

SW Maps

- <u>Free</u> GIS data collector app

- Available for Android(2016) and iOS(2022)

- Supports several GNSS instruments

Features useful with Low-cost GNSS Systems:

- Built-in NTRIP Client

- Base station antenna PCO correction

- Data logging for post-processing

# Applications: Rural Water Supply Surveying in Nepal

- The Sustainable WASH for All (SUSWA) Project, carried out under cooperation of the Government of Finland and the Government of Nepal

- Use of low-cost GNSS system for detail surveying rural water supply schemes in Karnali Province of Nepal alongside traditional methods

- Surveyors could be trained to use the GNSS receiver and the SW Maps app in 1-2 days.

- Designers have more information to work with

- Pressurized system with high elevation difference, accuracy of 1-3m from SBAS is sufficient. Can be improved with satellite based PPP.

Source: SUSWA (Facebook)

Surveying using Measuring Tape
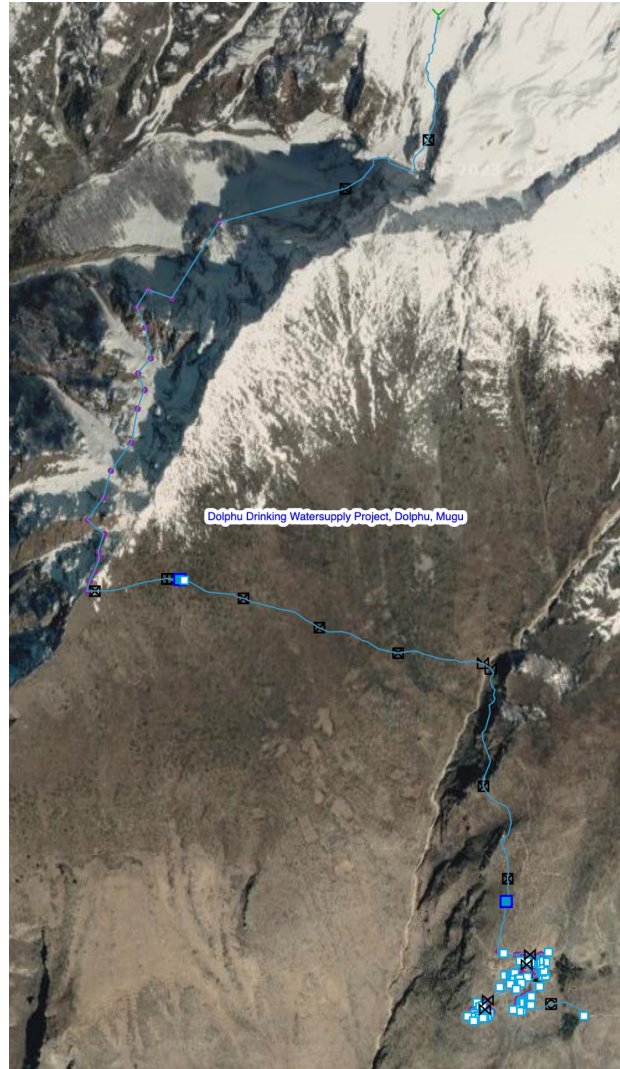
Water supply project designed using survey data from Low-Cost
GNSS System

Future Plans

- Low Cost GNSS CORS network
  - Plans to establish stations in universities in Nepal
  - Total cost including installation < $2500 for triple frequency system
  - Remote administration tool for CORS stations

- Improvement of SW Maps App with features for Low-Cost GNSS users
  - Point and line stake-out feature for construction projects
  - Import and export data in local co-ordinate systems

GNSS CORS Antenna at Western Region Campus, IOE Tribhuvan University Pokhara

Low-cost GNSS CORS at Khowpa College of Engineering, Tribhuvan University Bhaktapur

Thank You