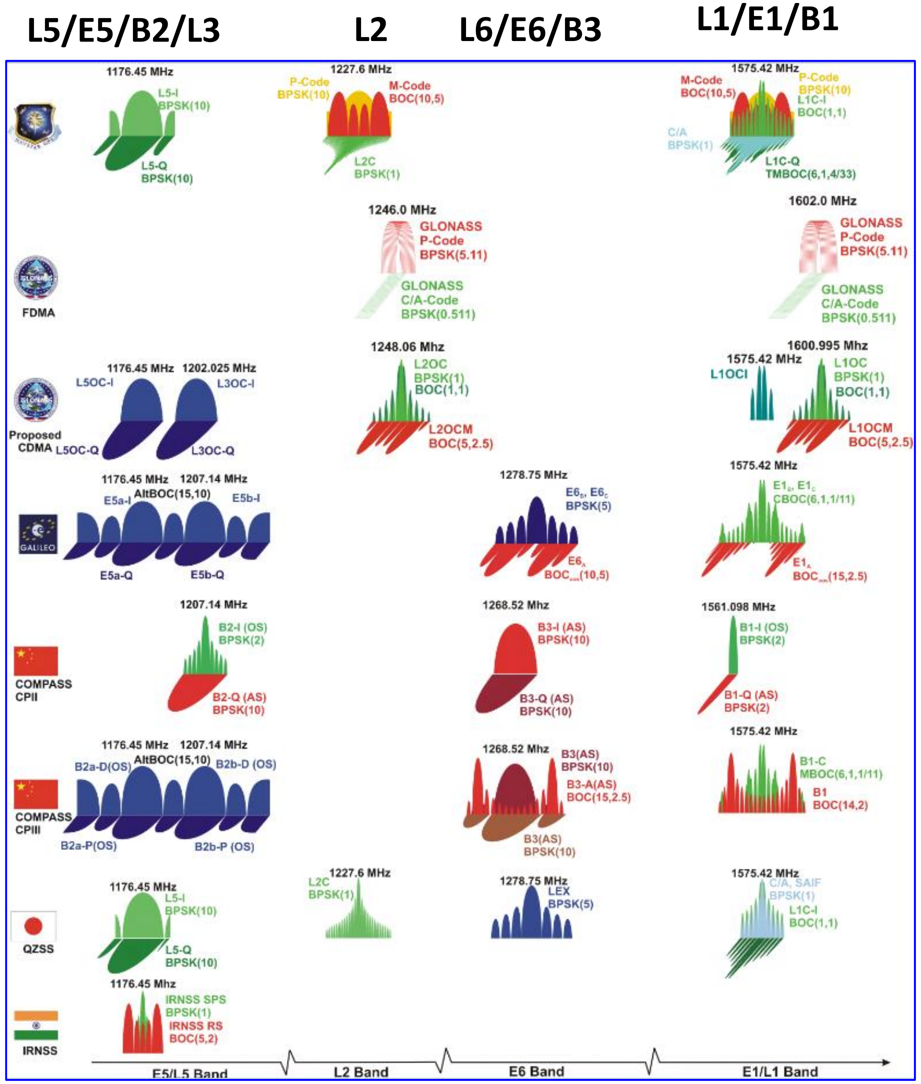
Workshop on GNSS for Policy and Decision Makers
21st January 2022

# Low-Cost and Smart-Phone Receiver Systems

Dinesh Manandhar, Associate Professor (Project)
Center for Spatial Information Science (CSIS), The University of Tokyo
dinesh@csis.u-tokyo.ac.jp

# High-End Survey Grade Receivers

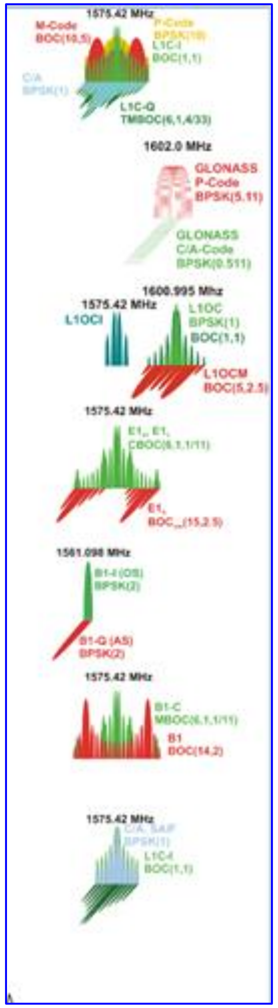
- Multi-frequency
  - GPS : L1/L2/L5
  - GLONASS : L1/L2/L3
  - GALILEO : E1/E5/E6
  - BDS : B1/B2/B3
  - QZSS : L1/L2/L5/L6
  - NAVIC : L5/S
- Multi-system
  - GPS, GLONASS, GALILEO, BeiDou, QZSS, NAVIC, SBAS etc
- Price varies from \$3,000 to \$30,000 or more (including antenna)



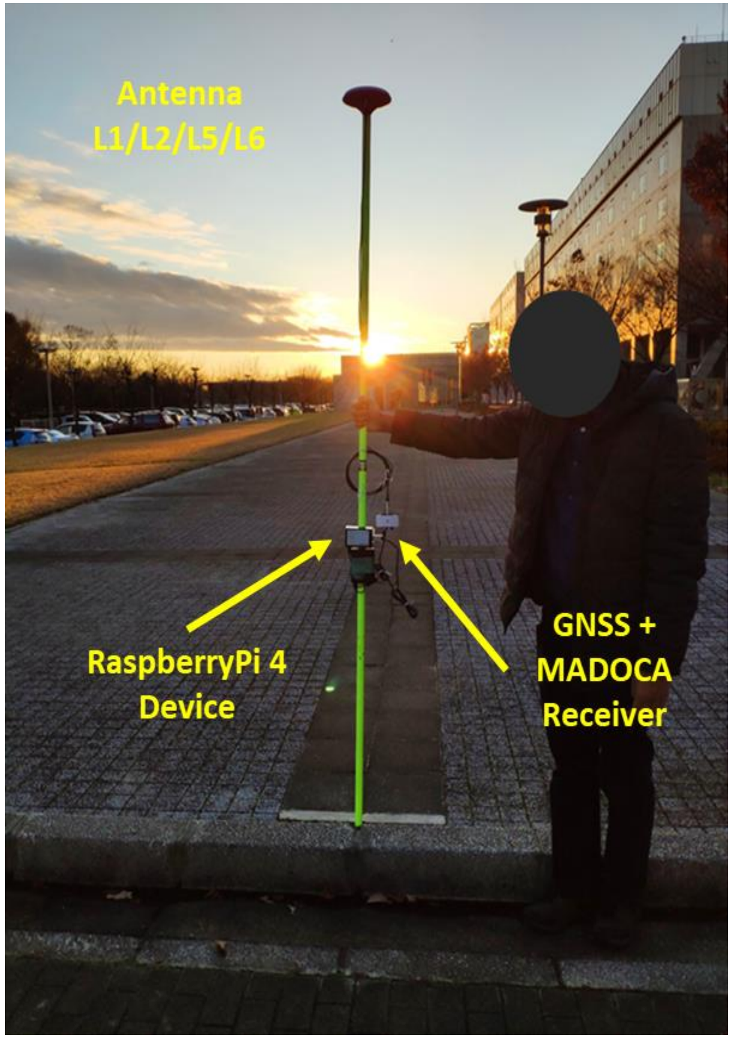
# Low-Cost Receivers

- Multi-System
  - GPS, GLONASS, GALILEO, BeiDou, QZSS, SBAS etc
- Basically Single Frequency
  - L1/E1/B1-Band
  - Very soon: Multi-System, Multi Frequency, L1/L2 or L1/L5
    - Future trend for Mass Market System will be L1/L5
  - Some chip makers have already announced Multi-System, Multi-Frequency GNSS Chips for Mass Market
- Low Cost:
  - Less than $1,000
    - Our Target: $100 including everything. (L1 band only receiver)
    - But, currently about $300 including Antenna and all necessary Hardware, Software
      - This is using Dual-Band Receiver and Antenna
    - In future, dual band low-cost receivers based on L1/L2 and L1/L5 will be available

**L1/E1/B1***



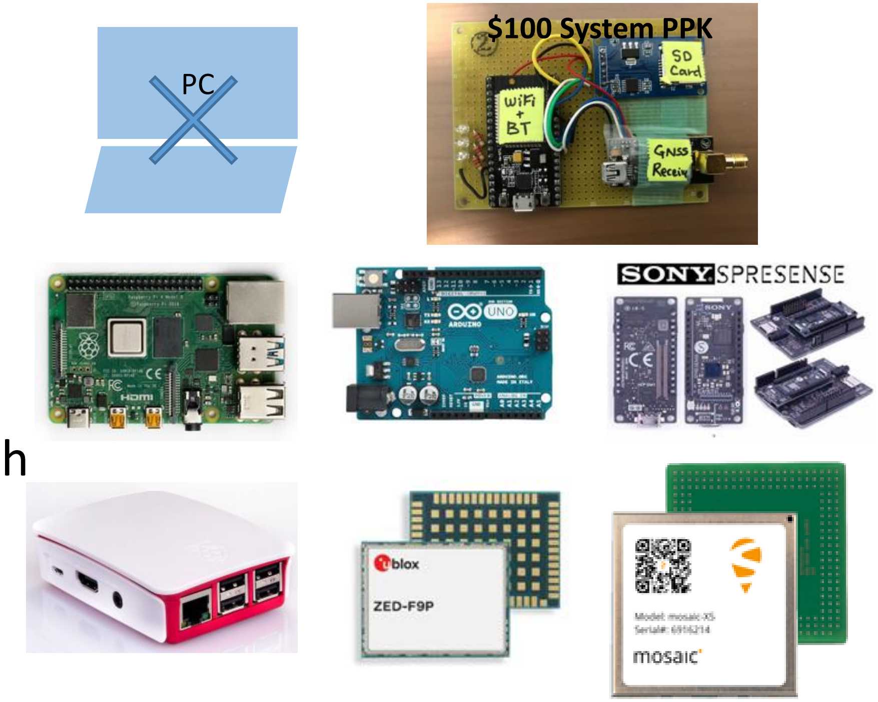
# Low-Cost High-Accuracy Receiver Systems
# RTKDROID, MADROID, MAD-WIN, MAD-π



# Objectives

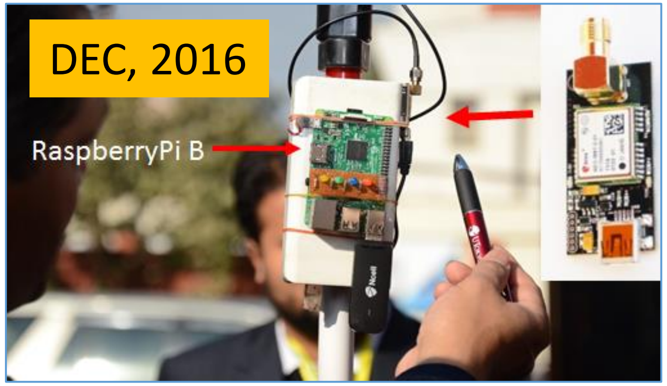
- Develop Low-Cost High-Accuracy Positioning Systems (L-CHAPS)
  - System Integration of commercially available receiver or module
    - For RTK and MADOCA
  - Avoid use of computer to minimize the cost
    - Use Single Board Computer (SBC)
      - RaspberryPi, Arduino, Spresense
    - Use Tablet or Smart-Phone
      - Android devices are quite flexible and easier to use
- Develop Easy to Use System in Field
  - A user without GNSS knowledge shall be able to use
  - Self-understanding interface
  - Suitable for remote operation and data logging
  - Operate with mobile power-banks
- Promote GNSS and MADOCA Technologies Abroad through
  - Lectures, Trainings, Seminars, Workshops and Events
  - Joint Research and Joint Projects

RTKDROID MAD-π RTKLIB MADROID MAD-WIN



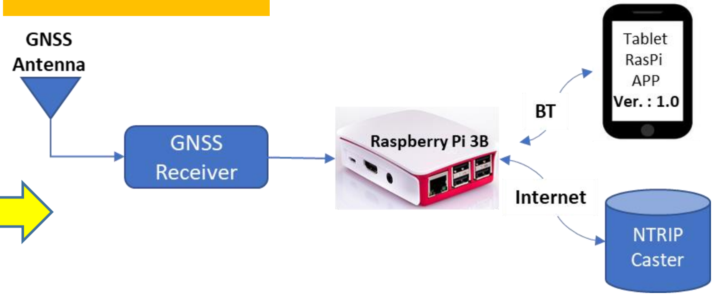

We have no intention to prefer any brand names mentioned in these slides. They are used only for reference.

# Low-Cost High-Accuracy Receiver system Development Cycle

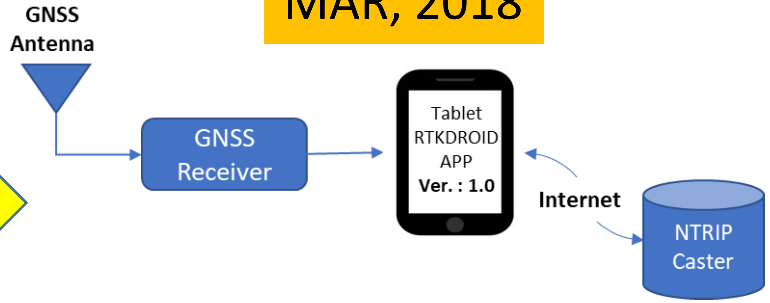



MAY, 2017

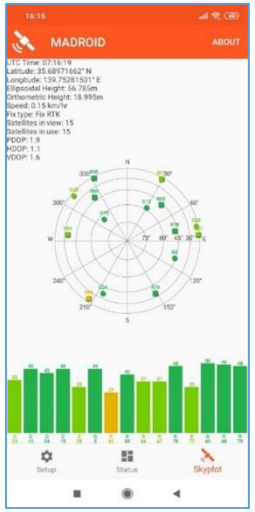
Low-Cost RTK

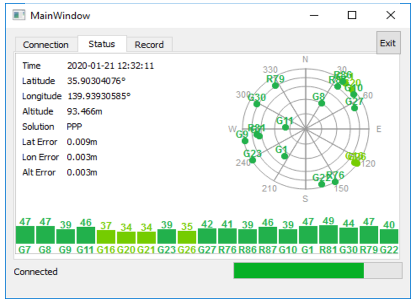


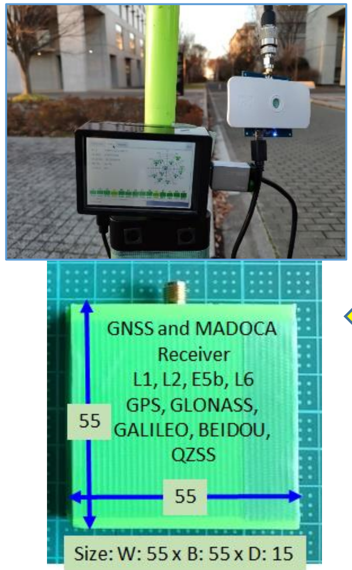

MAR, 2018




Low-Cost MADOCA

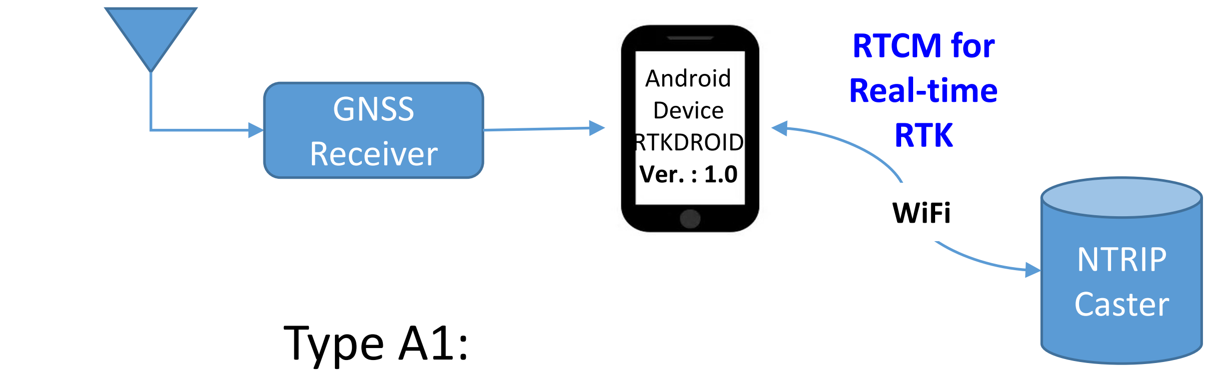

DEC, 2019

Enhancement of MADOCA System 2021

Android Device
RTK / MADOCA / EWS / SAR System
2022

**What type of smart-phone will emerge by 2025 ?**

# Type – A1: GNSS Receiver with Android Device




Type A1:
Rover Mode
Real-Time and Post-Processing RTK
Based on RTKLIB Engine
Real-time processing in Android Device
APP: RTKDroid

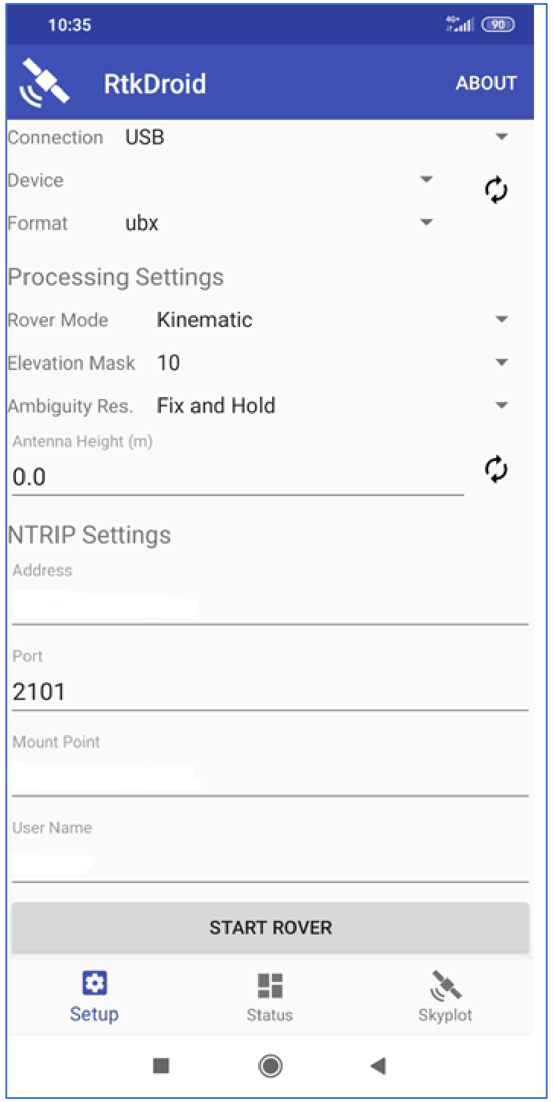
GNSS Receiver Module

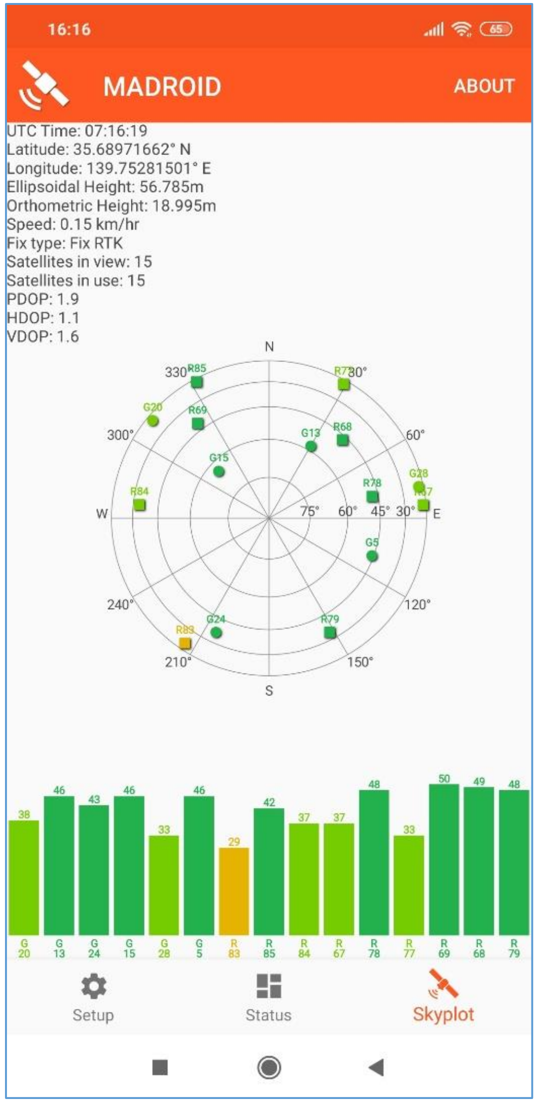
# Screen Shots of RTKDROID and MADROID

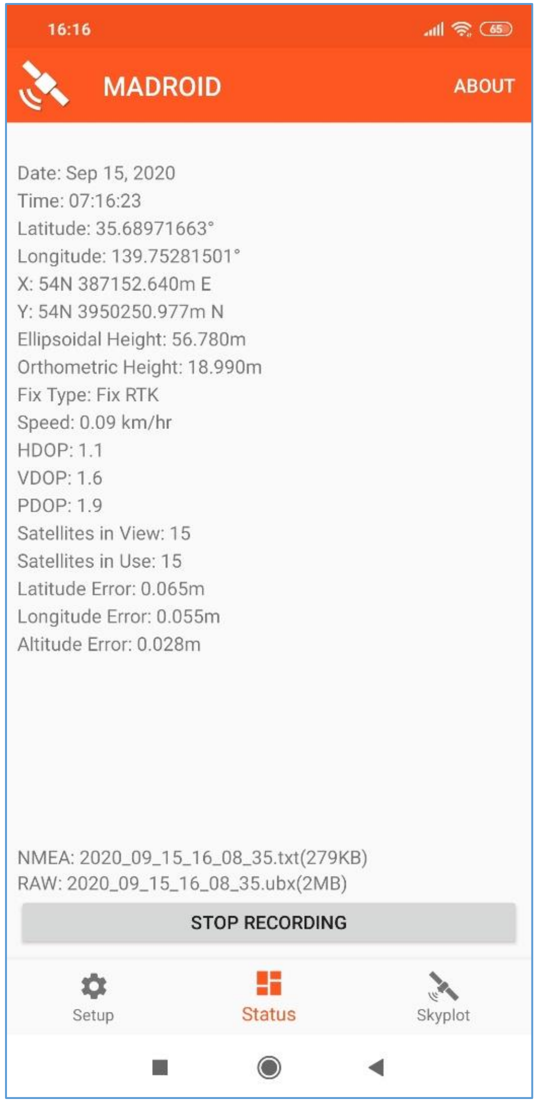
Connect GNSS receiver to Android device

(1) RTKDROID :
For RTK or PPK

(2) MADROID:
for MADOCA-PPP,
MADOCA-PPP/AR (future)

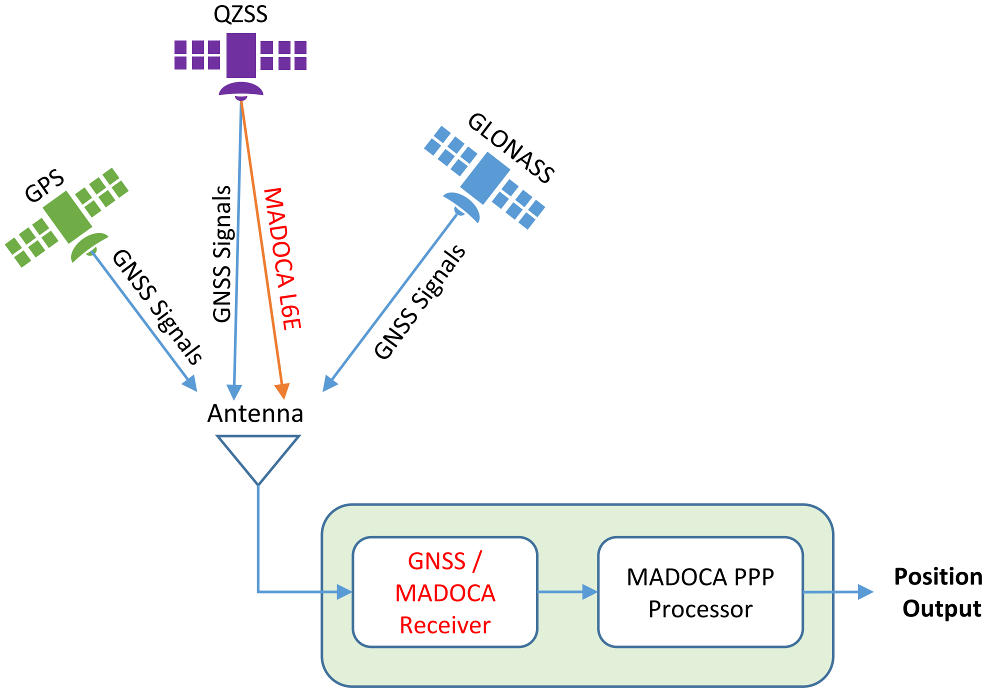


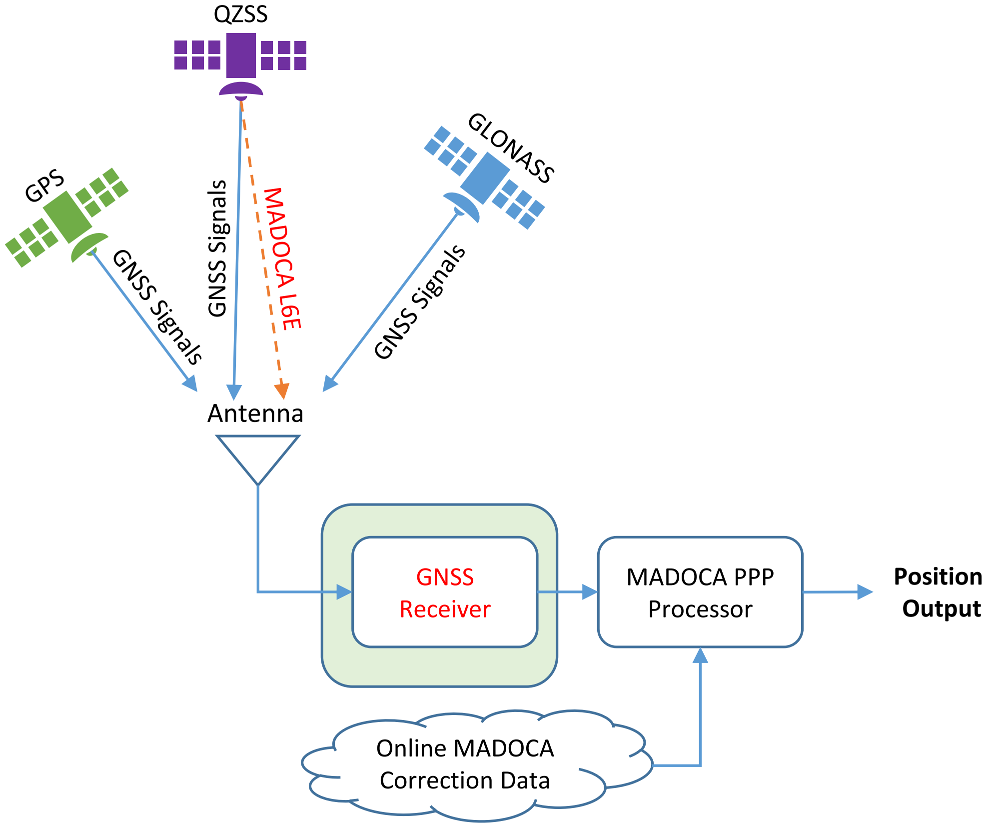



# MADOCA System: Direct from QZSS or Online Correction Data

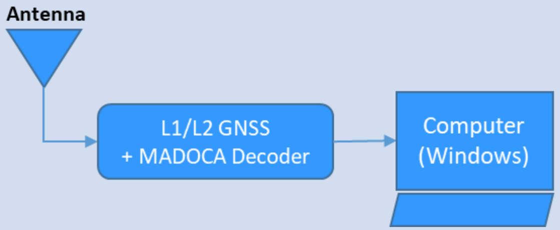
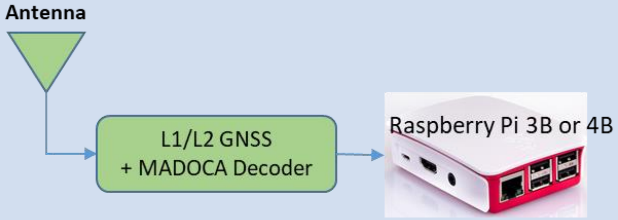
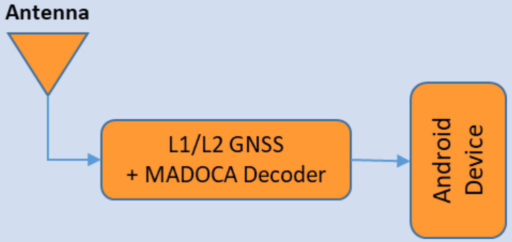
## GNSS Receiver + MADOCA Decoder



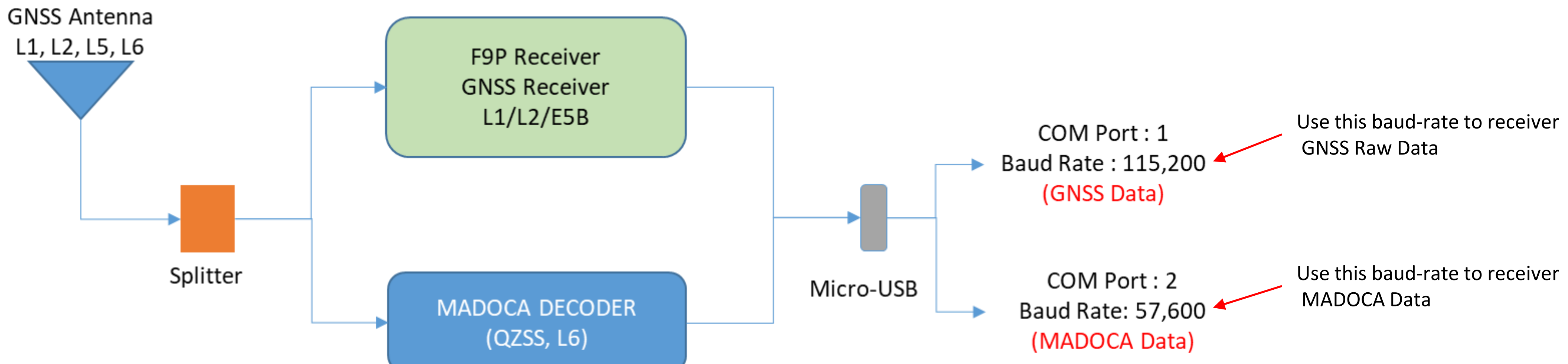

## GNSS Receiver Only

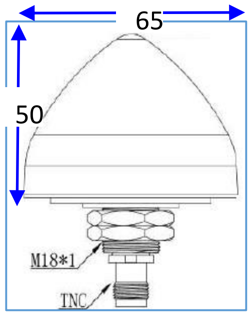


# Low-Cost MADOCA Receiver Systems: Product Types

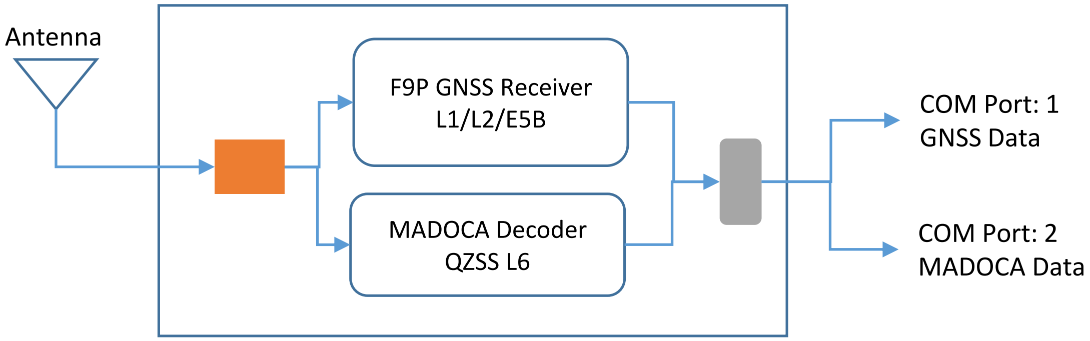
| | MAD-WIN | MAD-π | MADROID |
|---|---|---|---|
| Platform / OS | Windows | RaspberryPi 3B or 4B | Android Device |
| GNSS Receiver | Default : u-blox F9P<br>Other: Any dual-frequency Receiver | Default : u-blox F9P only | Default : u-blox F9P<br>Other: Any dual-frequency Receiver |
| MADOCA Receiver | U-blox D9 only | U-blox D9 only | NA (MADOCA Online Correction Data only) |
| GNSS Receiver Data Format | UBX, SBF, RTCM3 | UBX<br>SBF, RTCM3 (For online GNSS data) | UBX |
| MADOCA Correction Data Format (Satellite) | UBX only | UBX only | NA |
| MADOCA Correction Data Format (Online) | Online Services<br>from GPAS, UTokyo (Test Level)<br>UBX or RTCM3 | Online Services<br>from GPAS, UTokyo (Test Level)<br>Online Services<br>UBX or RTCM3 | GPAS Services,<br>RTCM3<br>UTokyo Online Service in the next release |
| System Architecture |  |  |  |

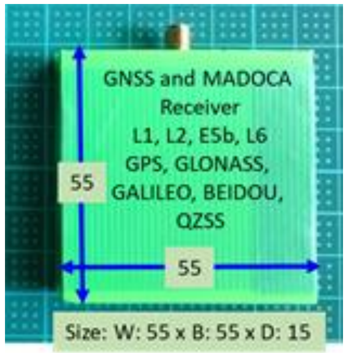
# MADOCA PPP Receiver System



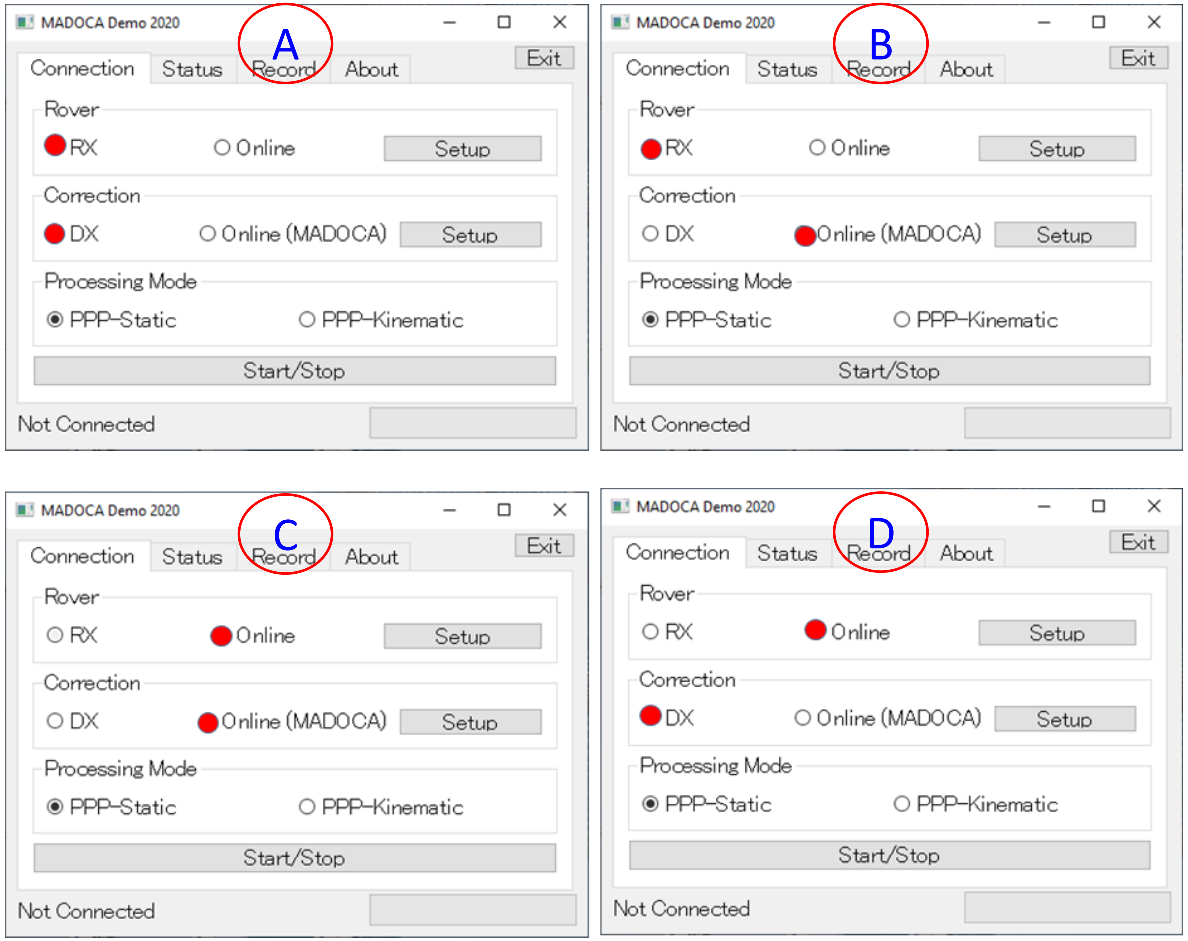




GNSS Antenna



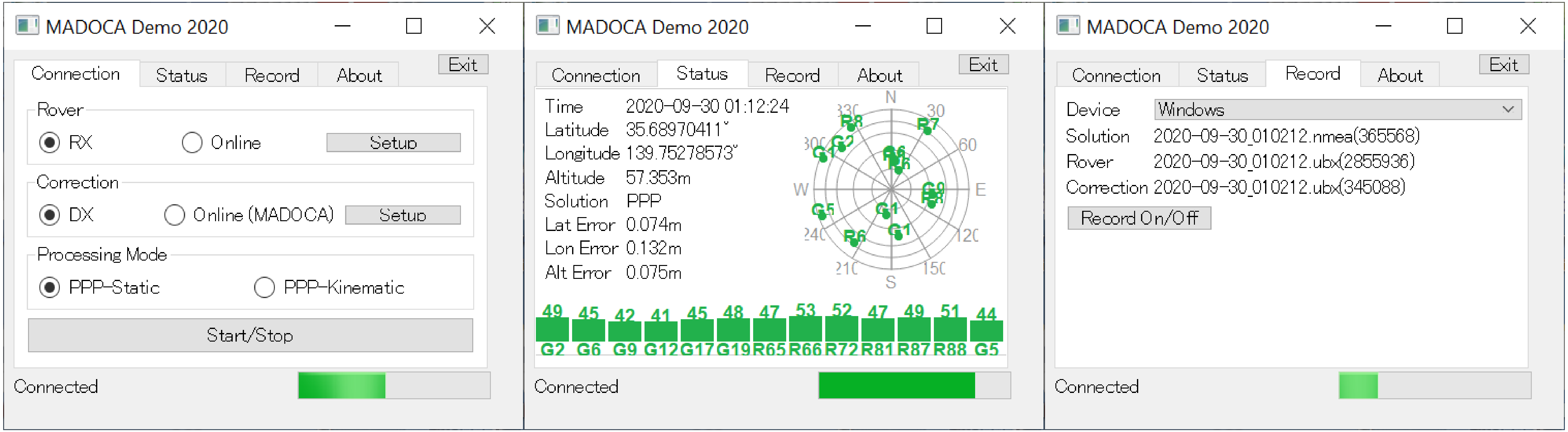



# MAD-WIN / MAD-PI User Interface




| Cases | GNSS Receiver | MADOCA Correction Data | Selection Setting in the Program |
|---|---|---|---|
| Case A | Connect Receiver Directly | Connect MADOCA Receiver Directly | RX and DX |
| Case B | Connect Receiver Directly | Get MADOCA correction data through NTRIP | RX and<br>Online (MADOCA) |
| Case C | Connect Receiver though NTRIP | Get MADOCA correction data through NTRIP | Online and<br>Online (MADOCA) |
| Case D | Connect Receiver though NTRIP | Connect MADOCA Receiver Directly | Online and DX |

# MAD-WIN / MAD-PI User Interface




Log Files:

1. Solution: MADOCA PPP Solution in NEMA format
2. Rover: Rover RAW Data in receiver's proprietary format

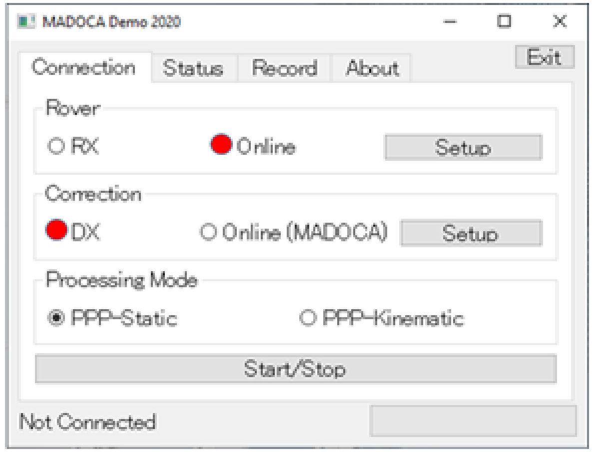
Can be used for PPK (Post-Processing Kinematic) Solution or Post-Processing PPP

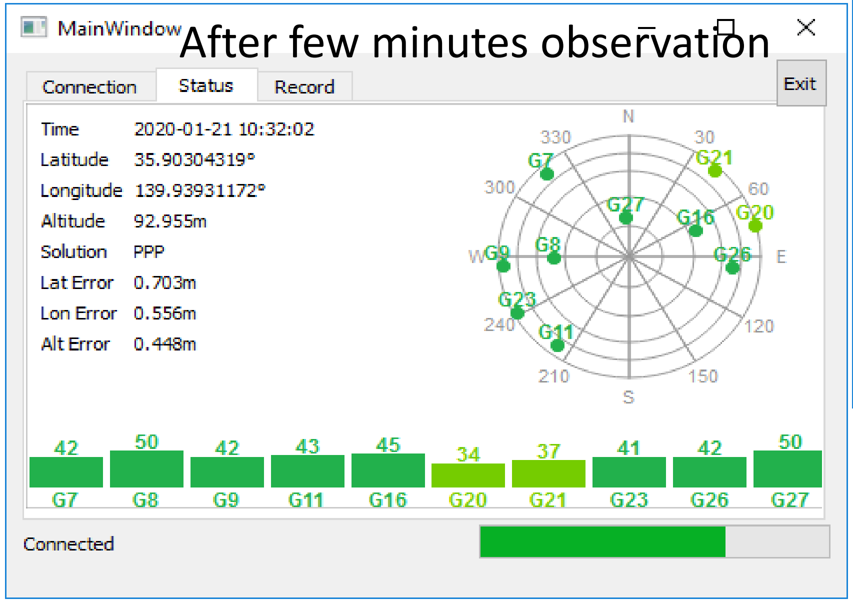
3. Correction: MADOCA PPP Correction Data in receiver's proprietary format

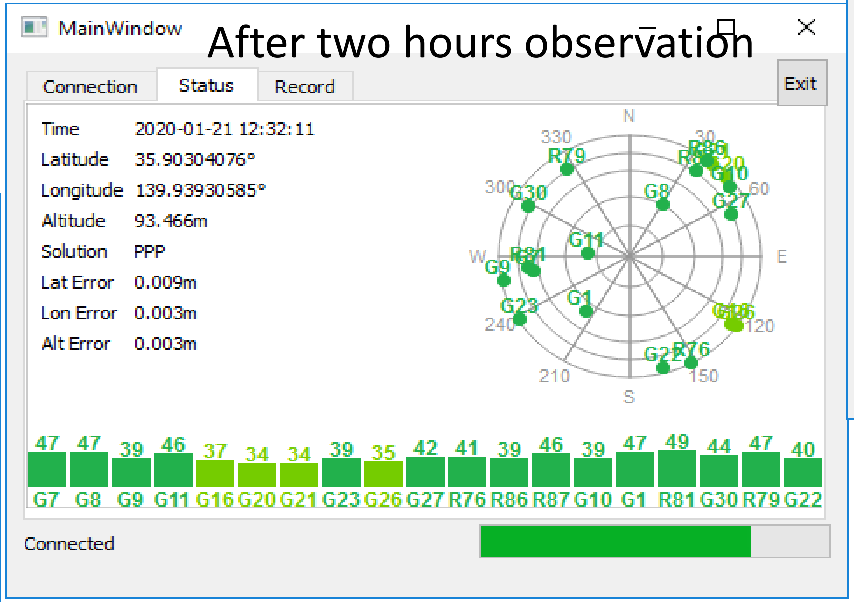
Can be used for Post-Processing MADOCA

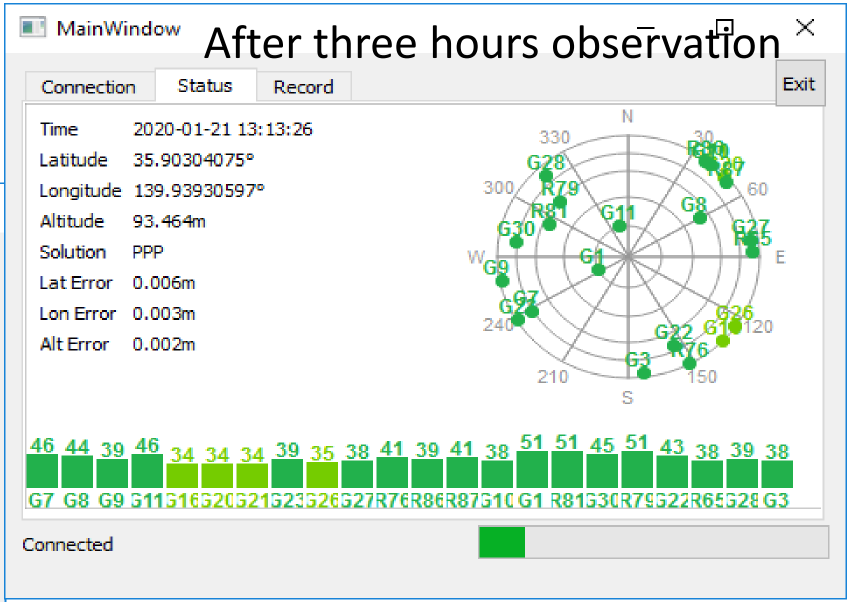
# MAD-WIN Data Observation

## Receiver: Online receiver access in Kashiwa / Correction Data: MADOCA Receiver in Bali



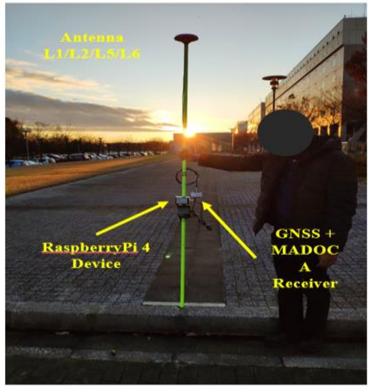



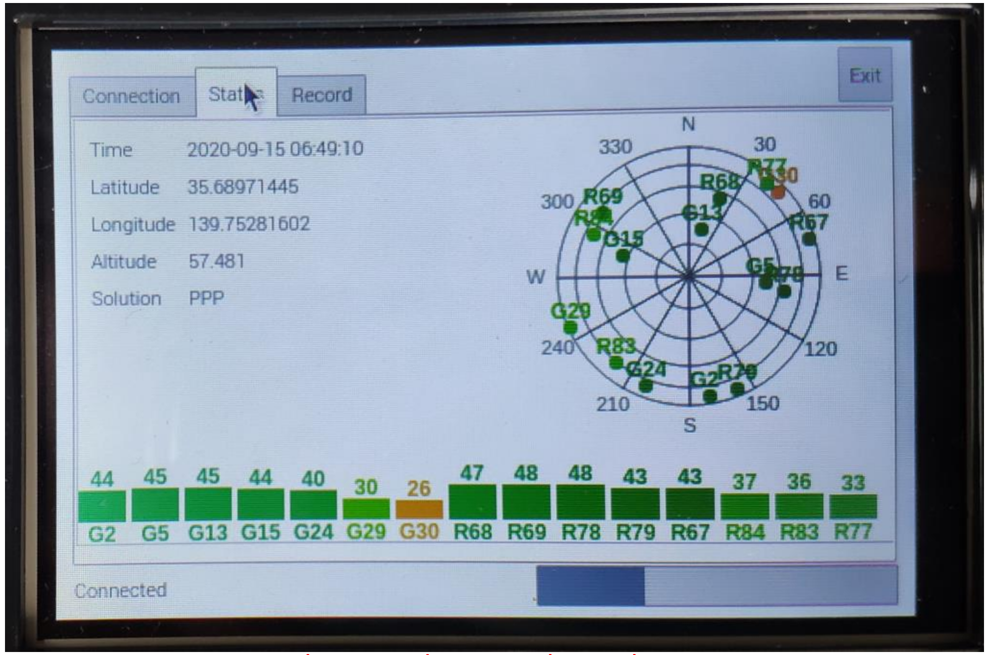



# MAD-PI:MADOCA with RaspberryPi Device

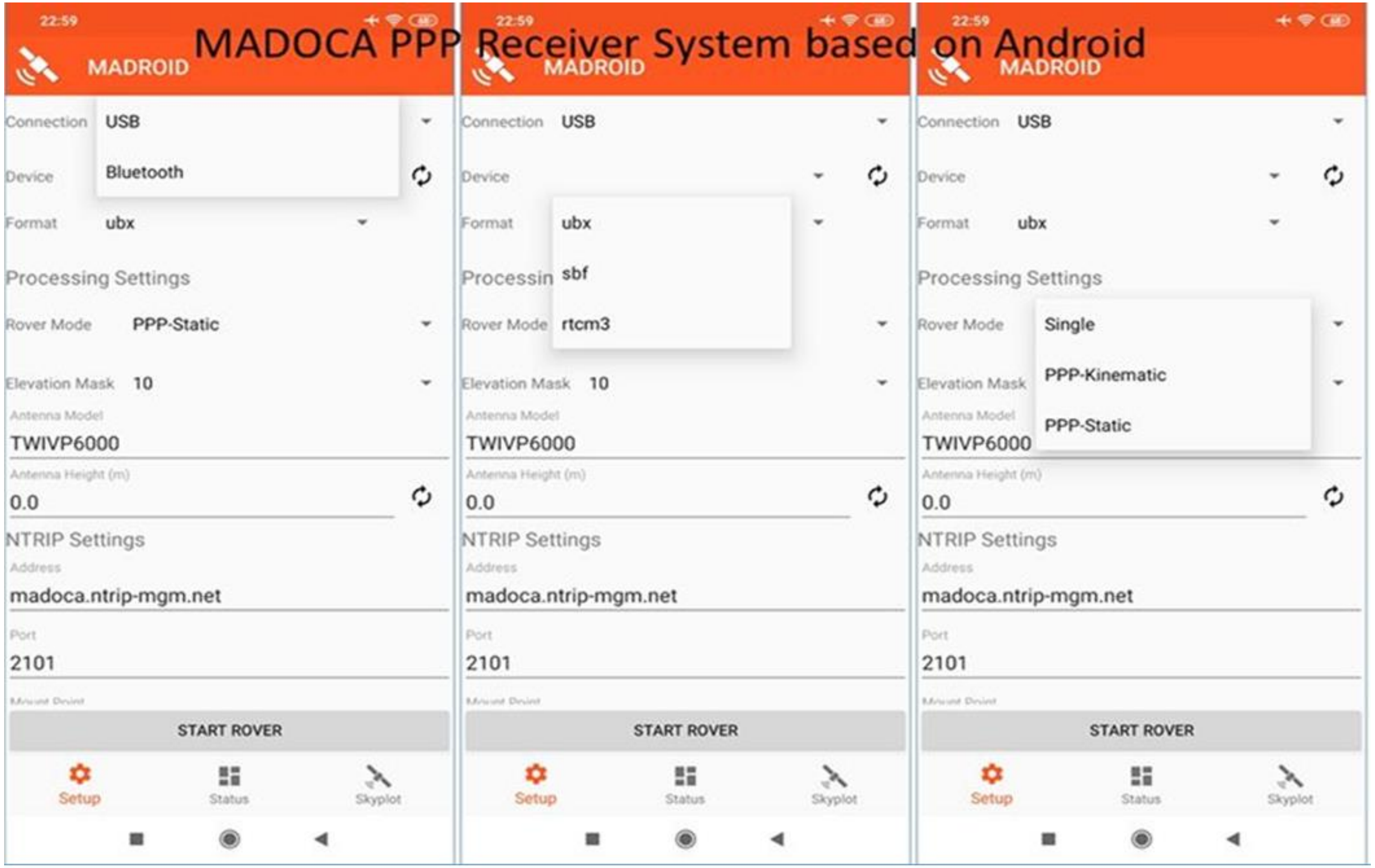
- MAD-Pi has been tested with RaspberryPi-3B device
  - It also works with RaspberryPi-4B
  - If the device does not work, please try with a different USB port
- Do not remove and insert SD Card several times. It may get damaged.
- Observation data can be logged to an external USB memory disk. Memory drive of upto 64GB is supported.
  - Files are created at 6-hour interval with Date/Time based filename.
- Ras-Pi 4 device consumes more power than Ras-Pi 3 device. Continuous operation of the device will generate heat. Keep the device in well ventilated area
  - Do not keep the device in a closed box
- We have set both Ras-Pi 3 and Ras-Pi 4 devices with touch screens for easy operation.
  - Mouse and External keyboard can be connected either via BT or USB ports
- Ras-Pi device can be connected by an Android device using BT

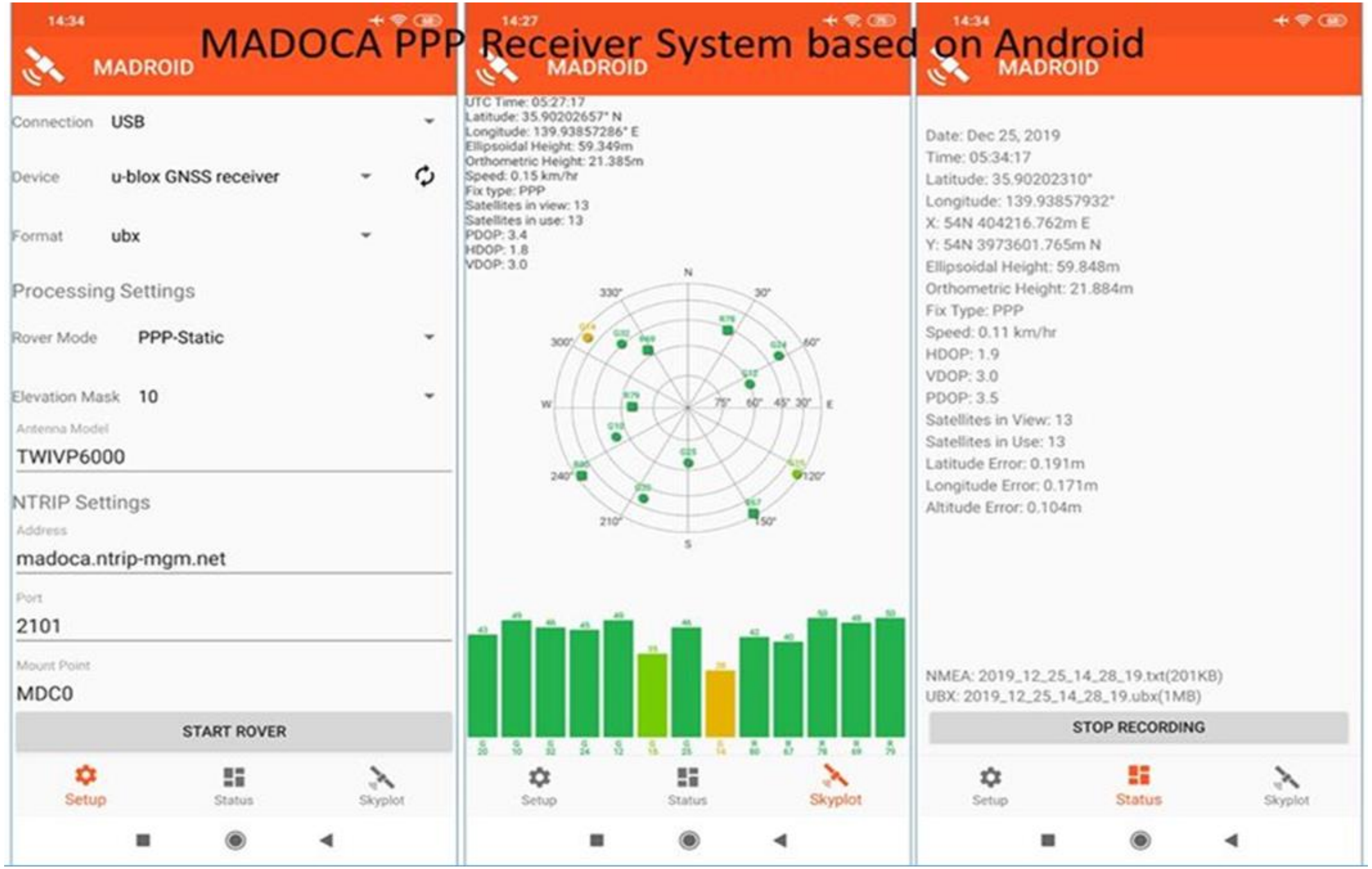




Raspberry-Pi device with Touch Screen

# MADROID: MADOCA with Android Device



# MADROID: MADOCA with Android Device



# GNSS Data from Android Device

# GNSS Data from Android Smart-Phone

- Android device can output GNSS only position data
  - Since it uses multiple satellite systems and some device also uses L1 and L5 bands – Accuracy is much better
- Many Android devices with OS 7.0 or higher can output Raw Data
  - These data are used for High-Accuracy data processing such as RTK
- Some devices have Multi-Frequency (L1/L5) GNSS receiver
  - Multi-System (GPS, GLONASS, GALILEO, BEIDOU, QZSS, NavIC)
  - Multi-Frequency (L1/E1/B1, L5/E5)
  - Outputs more than 40 channels
  - Some devices output NAV BIT Data, AGC values and Antenna Phase Center
- Google APIs are available to process GNSS raw data from a smart-phone

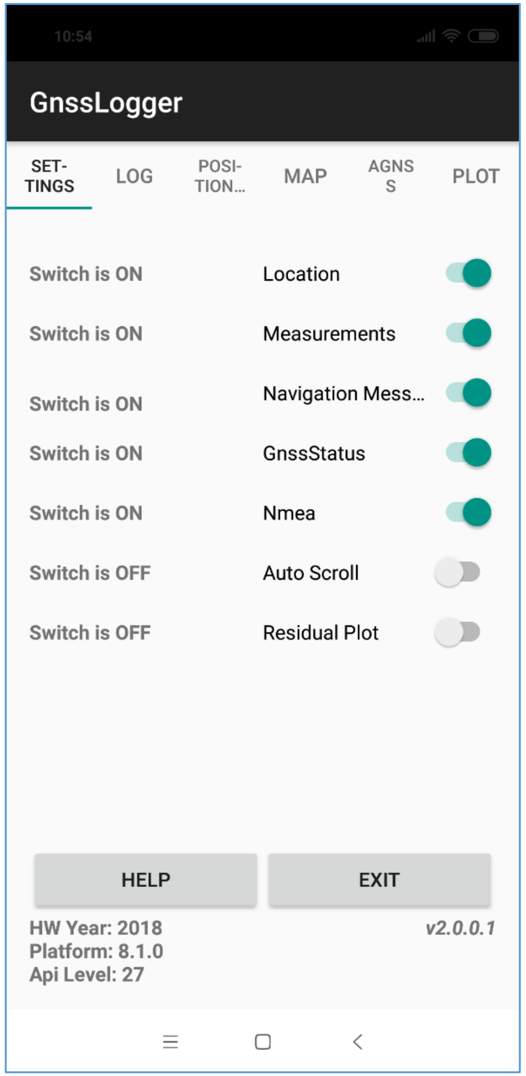
# GNSS Raw Data Compatible Smart-Phones

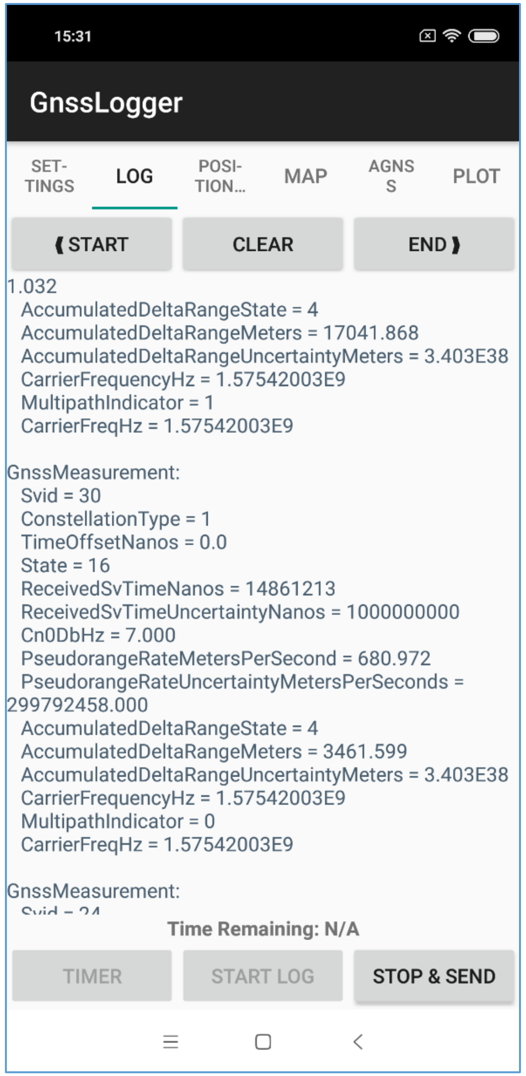
This List is Old. Please check for New List

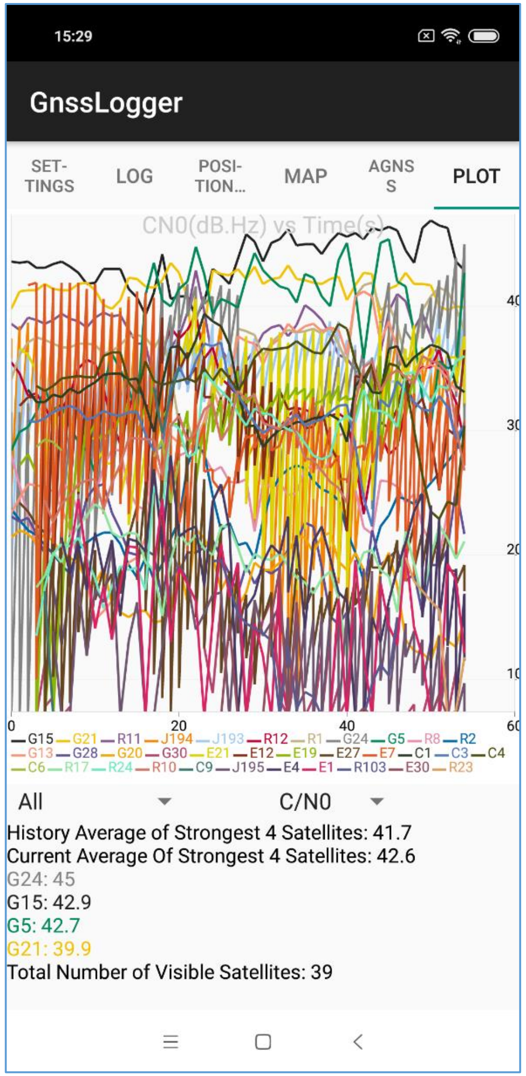
| | | | | | | Raw Data output used in System Score | | | | | Satellite Systems used in System Score | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S. No. | Model | Android version | System Score Max: 6 (D) | Function Score Max: 5 (E) | Total Score (D + E) | AGC | NAV MSG | Accumulated delta range | HW clock | L5 Support | GPS | GLO | GAL | BDS | QZSS | SBAS |
| 4 | Xiaomi Mi 8 | 8.1 | 5 | 4 | 9 | no | yes | yes | yes | yes | yes | yes | yes | yes | yes | no |
| 31 | Samsung S8 | 7 | 5 | 3 | 8 | no | yes | yes | yes | no | yes | yes | yes | yes | yes | no |
| 33 | Huawei P10 | 7 | 5 | 3 | 8 | no | yes | yes | yes | no | yes | yes | yes | yes | yes | no |
| 42 | Huawei Mate 20 X | 9 | 4 | 4 | 8 | no | yes | yes | yes | yes | yes | yes | yes | no | yes | no |
| 19 | Google Pixel 2 XL | 8 | 5 | 2 | 7 | yes | no | no | yes | no | yes | yes | yes | yes | yes | no |
| 20 | Google Pixel 2 | 8 | 5 | 2 | 7 | yes | no | no | yes | no | yes | yes | yes | yes | yes | no |
| 22 | Samsung Note 8 | 7.1 | 4 | 3 | 7 | no | yes | yes | yes | no | yes | yes | yes | yes | no | no |
| 1 | Pixel 3 XL | 9 | 4 | 3 | 7 | yes | no | yes | yes | no | yes | yes | yes | yes | no | no |
| 2 | Pixel 3 | 9 | 4 | 3 | 7 | yes | no | yes | yes | no | yes | yes | yes | yes | no | no |
| 43 | Huawei Mate 20 RS | 9 | 4 | 3 | 7 | no | no | yes | yes | yes | yes | yes | yes | yes | no | no |
| 44 | Huawei Mate 20 Pro | 9 | 4 | 3 | 7 | no | no | yes | yes | yes | yes | yes | yes | yes | no | no |
| 45 | Huawei Mate 20 | 9 | 4 | 3 | 7 | no | no | yes | yes | yes | yes | yes | yes | yes | no | no |
| 10 | Huawei P20 | 8.1 | 3 | 3 | 6 | no | yes | yes | yes | no | yes | yes | no | no | yes | no |
| 11 | Samsung Galaxy S9 | 8 | 3 | 3 | 6 | no | yes | yes | yes | no | yes | yes | no | no | yes | no |
| 18 | Huawei Mate 10 Pro | 8 | 3 | 3 | 6 | no | yes | yes | yes | no | yes | yes | no | no | yes | no |

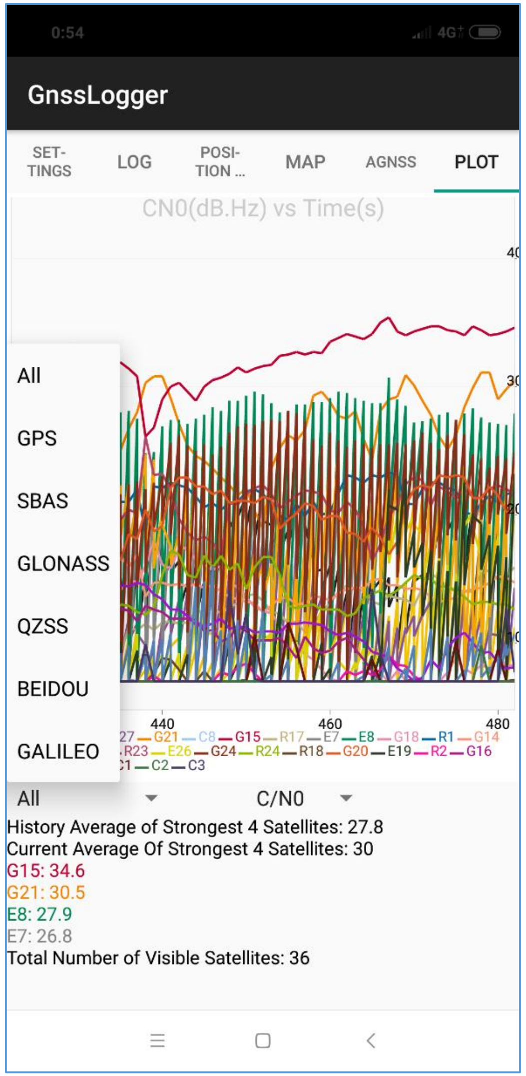
Check ➔ https://developer.android.com/guide/topics/sensors/gnss for Latest Updates

# Android Raw Data Logging Tool – 1: GnssLogger



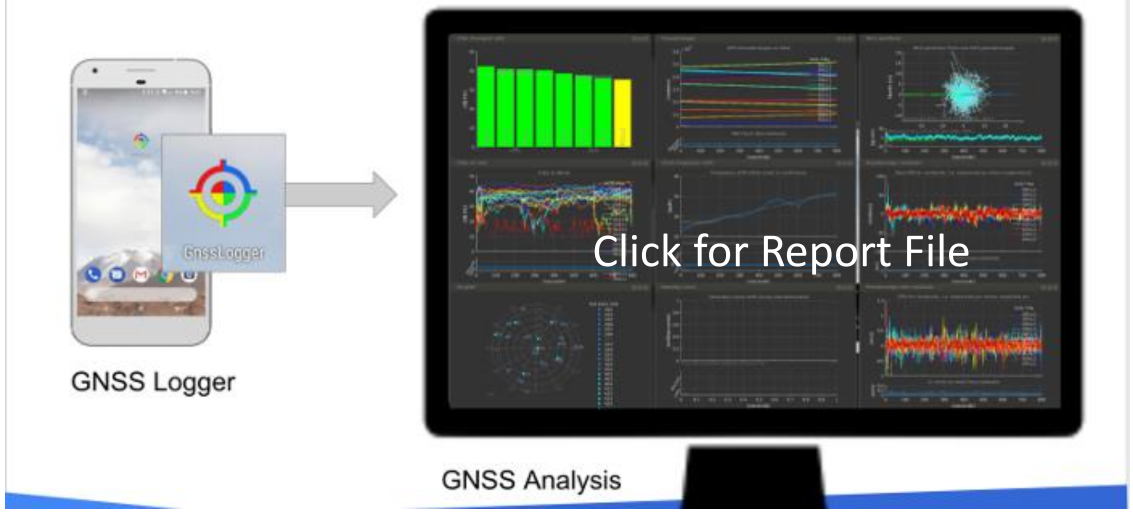



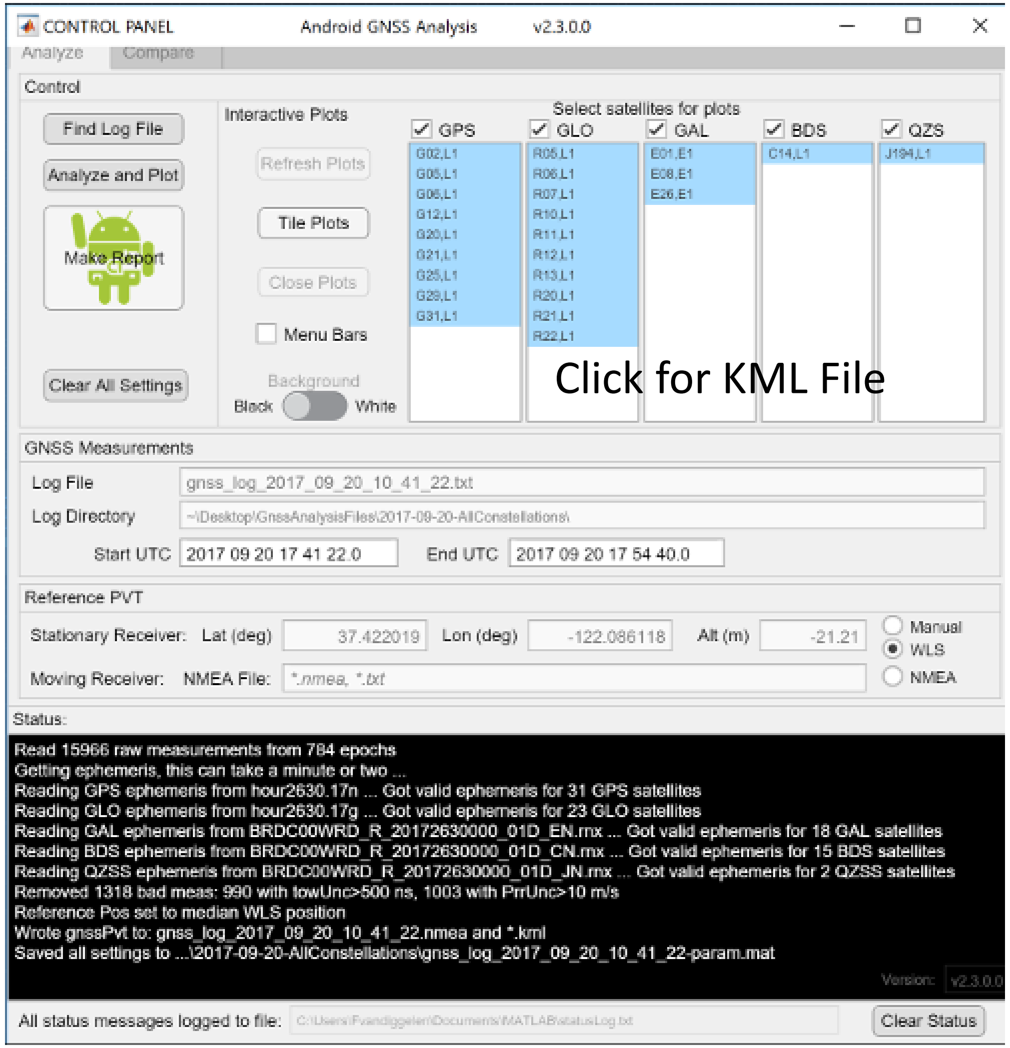
# GNSS Raw Data Analysis Tool for GnssLogger

- GNSS Analysis APP
  - Matlab-based Tool
  - Linux, Windows, MacOS
  - Version 2.6.3.0
  - Release Notes: https://developer.android.com/guide/topics/sensors/gnss#releaseGNSS Analysis app v2.6.3.0 release notes.

New Version V4.0.0.0 is available.
Download new version

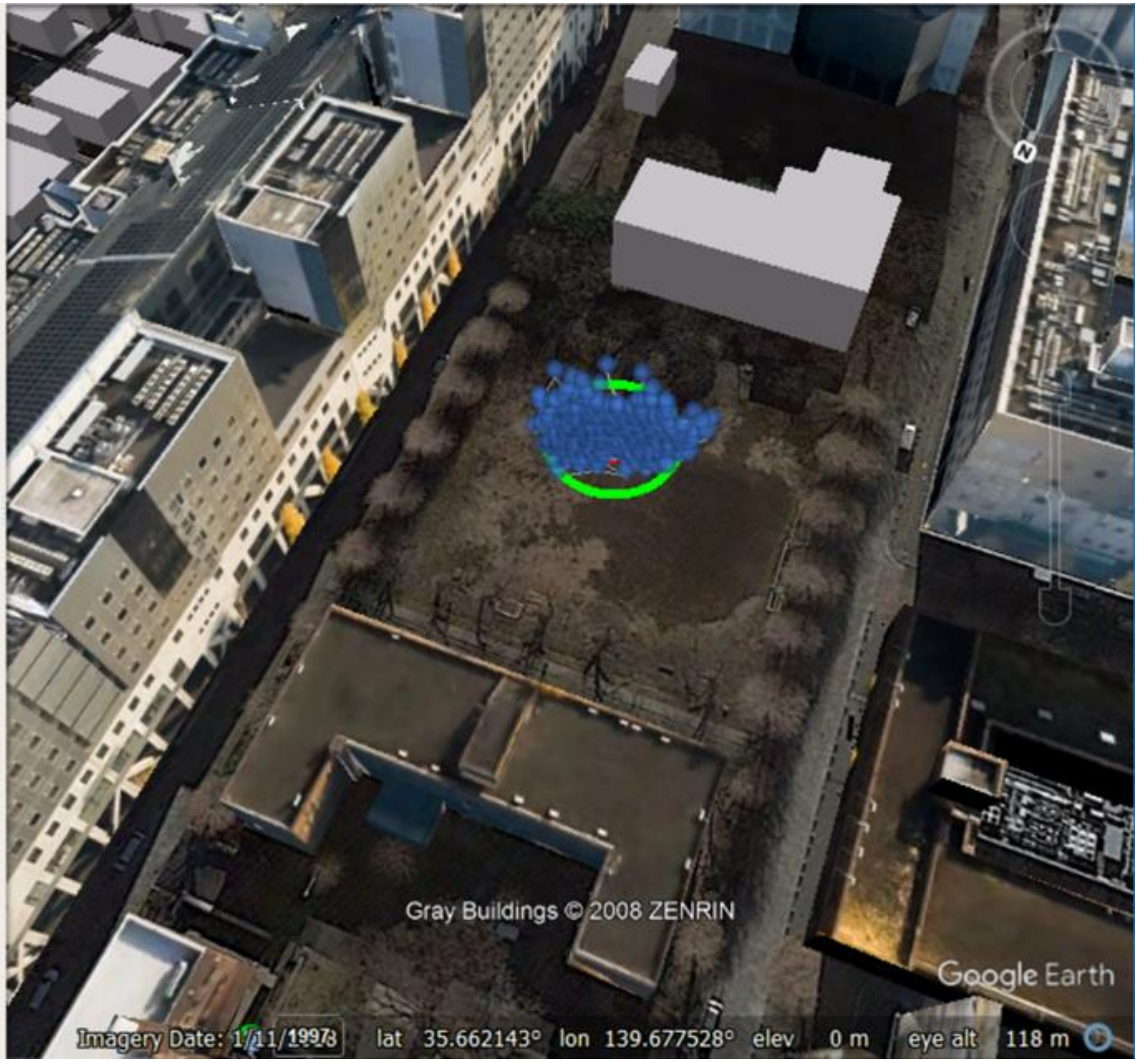



The GNSS Analysis app is built on MATLAB, but you don't need to have MATLAB to run it. The app is compiled into an executable that installs a copy of the MATLAB Runtime.



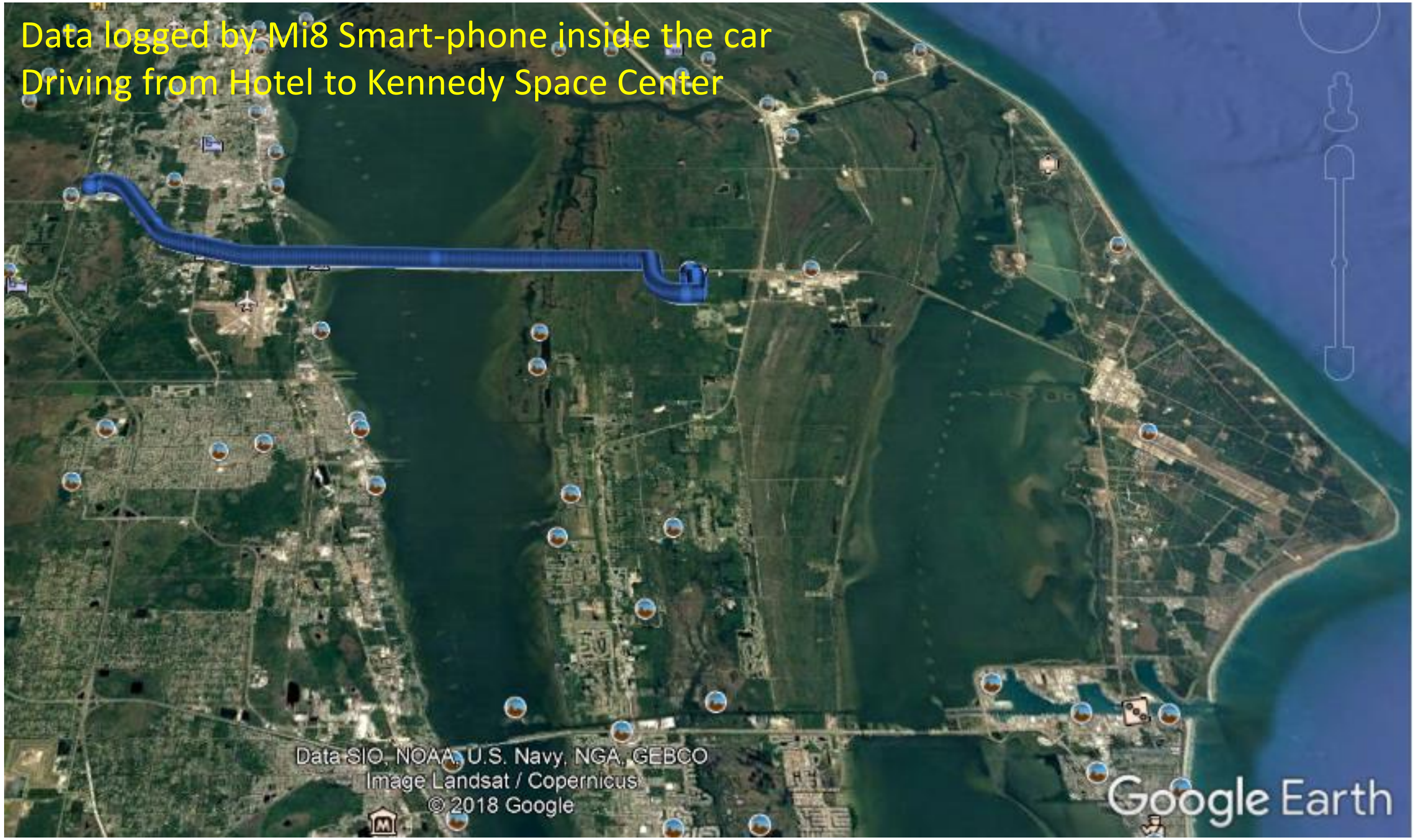
# Position Output from Android GNSS Receiver, Tokyo University, Komaba Campus

- Standard Position Computation
  - No DGPS or RTK Corrections
  - All visible GNSS Satellites are used
  - Frequency : L1/L5/E5
  - Surrounding : Tall Buildings around



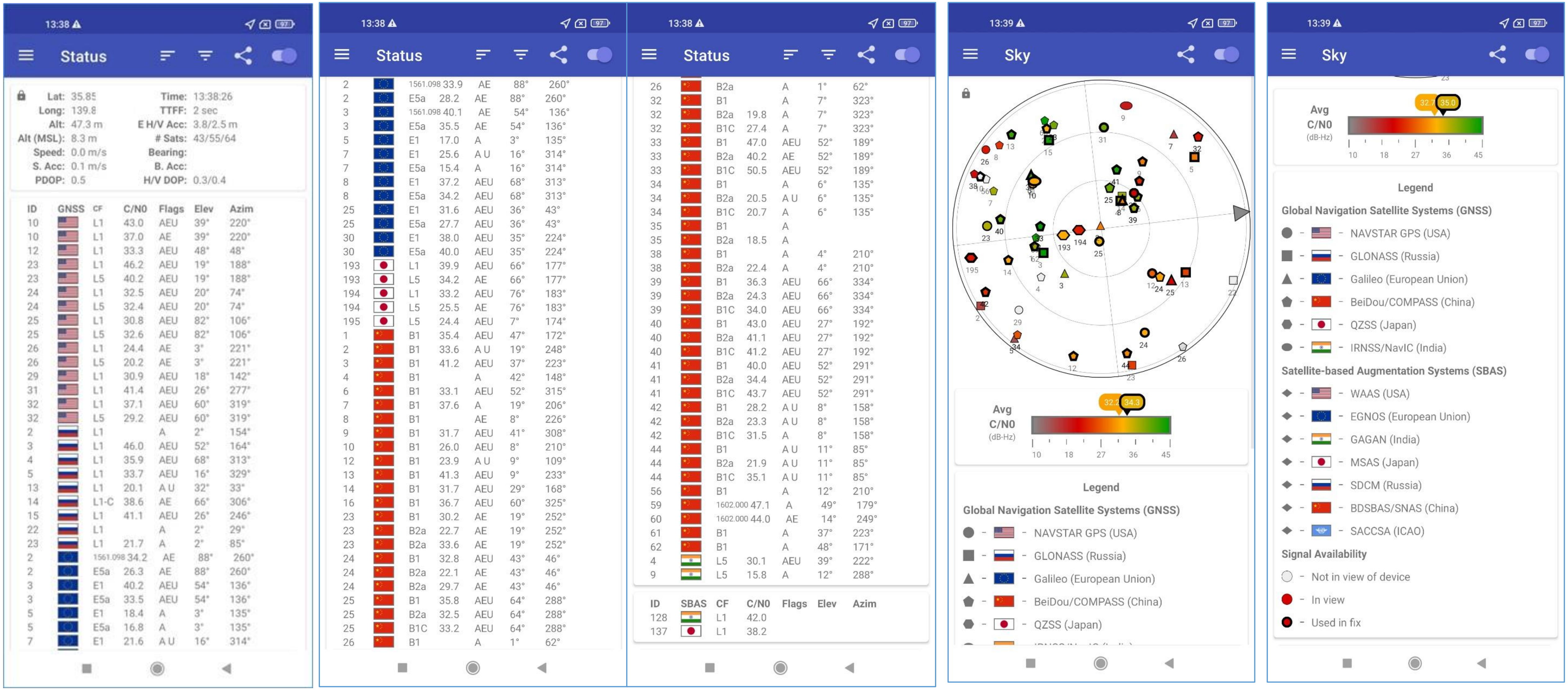
# Output from GNSS Analysis Tool, Data Logged by GNSSLogger

Location:
Kennedy Space Center
Florida

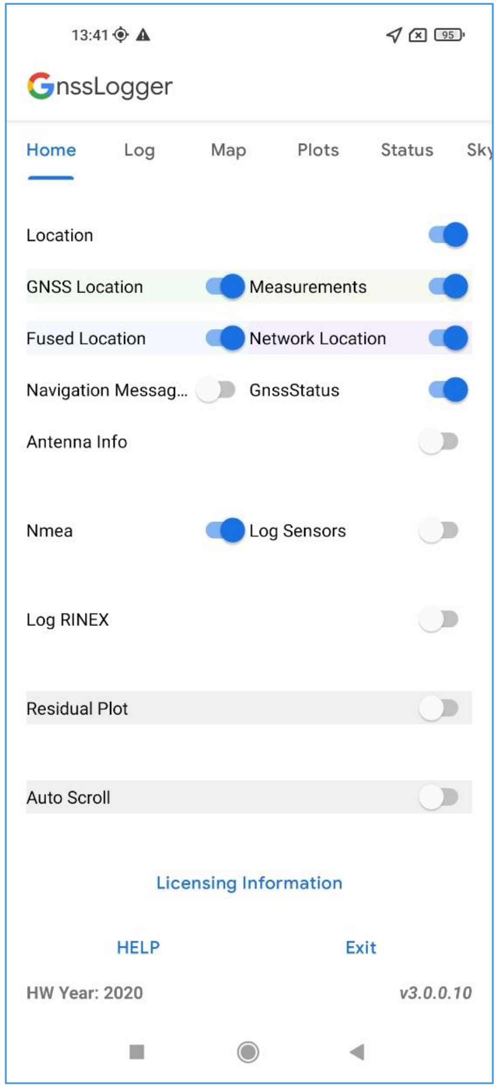


# Output from GNSS Analysis Tool, Data Logged by GNSSLogger

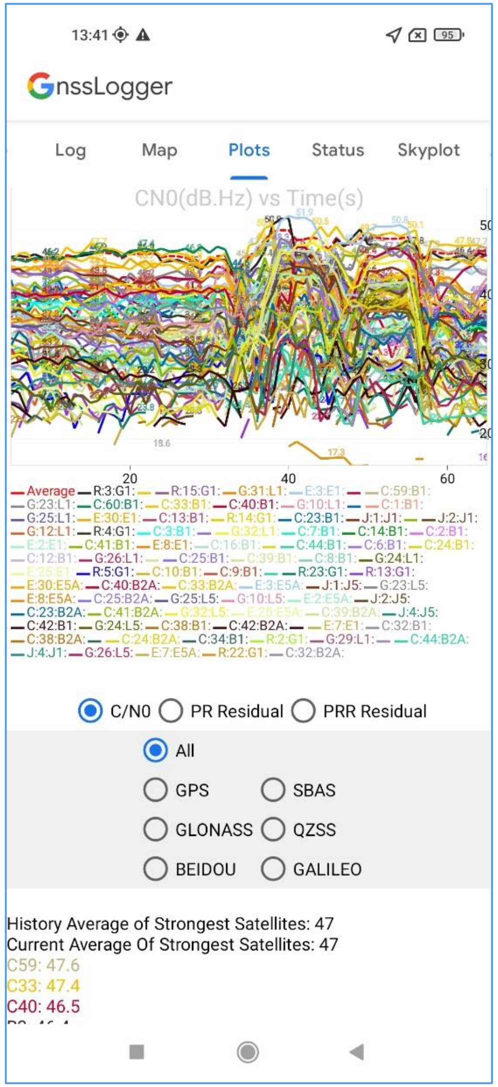
# Xiaomi Mi11 Lite 5G Screen Shots



# Xiaomi Mi11 Lite 5G Screen Shots








# Sample GNSS Raw Data from Mi11 Lite 5G

Sample GNSS raw data can be downloaded from the following website:
https://home.csis.u-tokyo.ac.jp/~dinesh/GNSS_Train.htm
Data were taken at the same time by using 4 or 5 different types of devices.
This will help to compare accuracy from different devices as well.

| | Smart-Phone Data | | | | | |
|---|---|---|---|---|---|---|
| | Xiaomi Mi8 (a) | Xiaomi Mi8 (b) | Xiaomi Mi8 (c) | Xiaomi Mi11 Lite 5G | OppoReno 3 A | |
| Day 1 | Data 01 | Data 02 | Data 03 | Data 08<br>Data 09 | Data 10 | |
| Day 2 | Data 04 | Data 05<br>Data 06 | Data 07 | | | |
| | | | | | | |

GNSS Raw Data from android devices open new opportunities to develop location based applications with high accuracy that were not possible before.