Low-Cost High-Accuracy Receiver for Education, Training and GIS Data Collection

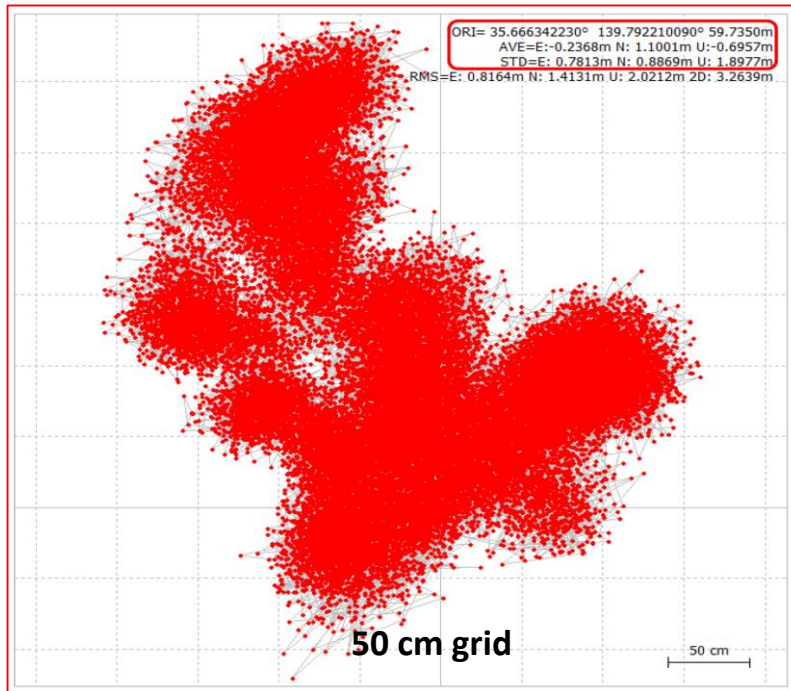## Dinesh Manandhar

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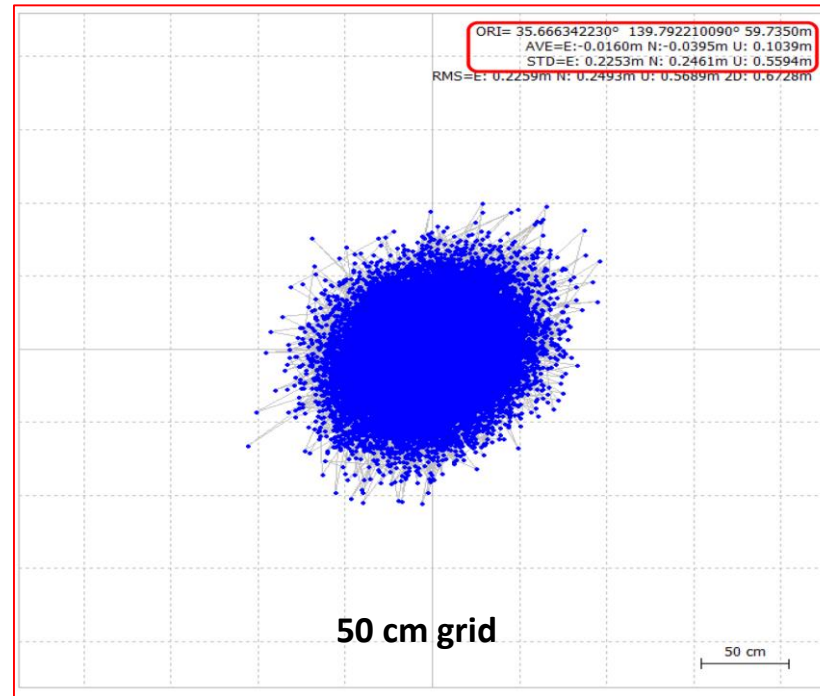Contact Information: dinesh@iis.u-tokyo.ac.jp

High Accuracy Receivers are Expensive

- High-Accuracy Survey Grade Receivers are multi-frequency and multi-system receivers
  - L1/L2/L5, G1/G2, B1/B2/B3 etc
  - GPS, GLONASS, BGALILEO, BeiDou, QZSS etc
  - Price varies from $3, 000 to $30,000 or more.
- However, Low Cost Receivers are also capable of
  - Multi-System: GPS, GLONASS, GALILEO, BeiDou, QZSS, SBAS etc
  - Basically only in L1-Band Frequency
  - Low Cost: $300 (Multi-GNSS, L1 Only)
  - Very soon: Multi-System, Multi Frequency, L1/L2/L5
    - Broadcom, u-Blox and ST Micro already announced Multi-System, Multi-Band GNSS Chips for Mass Market
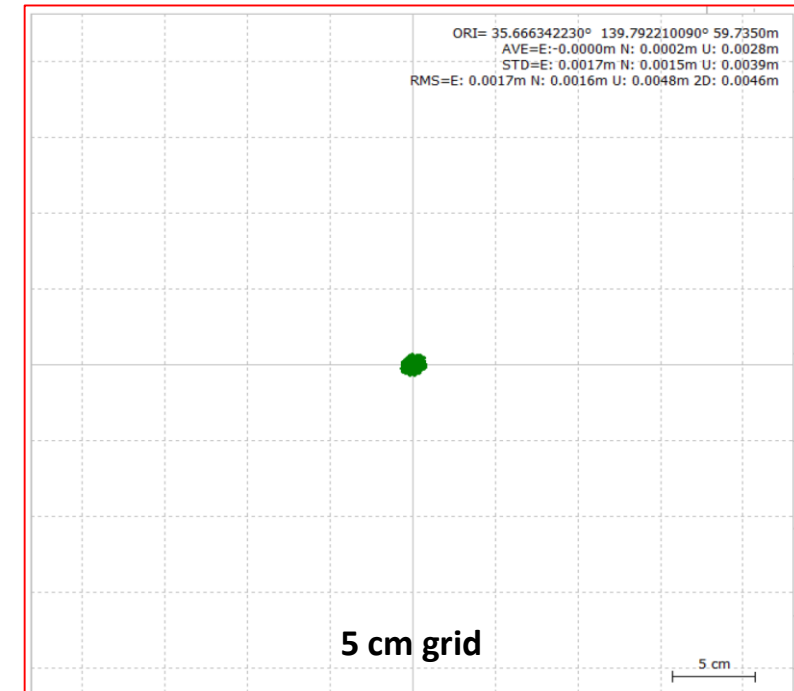
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How accurate is GPS Position?

ORI= 35.666342230° 139.792210090° 59.7350m
AVE=E:-0.2368m N: 1.1001m U:-0.6957m
STD=E: 0.7813m N: 0.8869m U: 1.8977m
RMS=E: 0.8164m N: 1.4131m U: 2.0212m 2D: 3.2639m

50 cm grid

50 cm

SPP (Single Point Position)

ORI= 35.666342230° 139.792210090° 59.7350m
AVE=E:-0.0160m N:-0.0395m U: 0.1039m
STD=E: 0.2253m N: 0.2461m U: 0.5594m
RMS=E: 0.2259m N: 0.2493m U: 0.5689m 2D: 0.6728m

50 cm grid

50 cm

DGPS (Differential GPS)

ORI= 35.666342230° 139.792210090° 59.7350m
AVE=E:-0.0000m N: 0.0002m U: 0.0028m
STD=E: 0.0017m N: 0.0015m U: 0.0039m
RMS=E: 0.0017m N: 0.0016m U: 0.0048m 2D: 0.0046m

5 cm grid

5 cm

RTK (Real Time Kinematic)

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Errors in GPS Observation (L1C/A Signal)

Error Sources	One-Sigma Error , m		Comments
	Total	DGPS	
Satellite Orbit	2.1	0.0	Common errors are removed
Satellite Clock	2.1	0.0	
Ionosphere Error	4.0	0.4	Common errors are reduced
Troposphere Error	0.7	0.2	
Multipath	1.4	1.4	
Receiver Circuits	0.5	0.5	

If we can remove common errors, position accuracy can be increased.
Common errors are: Satellite Orbit Errors, Clock Errors and Atmospheric Errors (within few km)

Table Source : http://www.edu-observatory.org/gps/gps_accuracy.html#Multipath

Principle of Differential Correction

Send Correction Data to Rover
For Real-Time Position
For RTK, both rover and base receivers
need to use the same satellites

Base-Station
Antenna is installed at a
known-position

Rover
User in the Field
(Either fixed or moving)
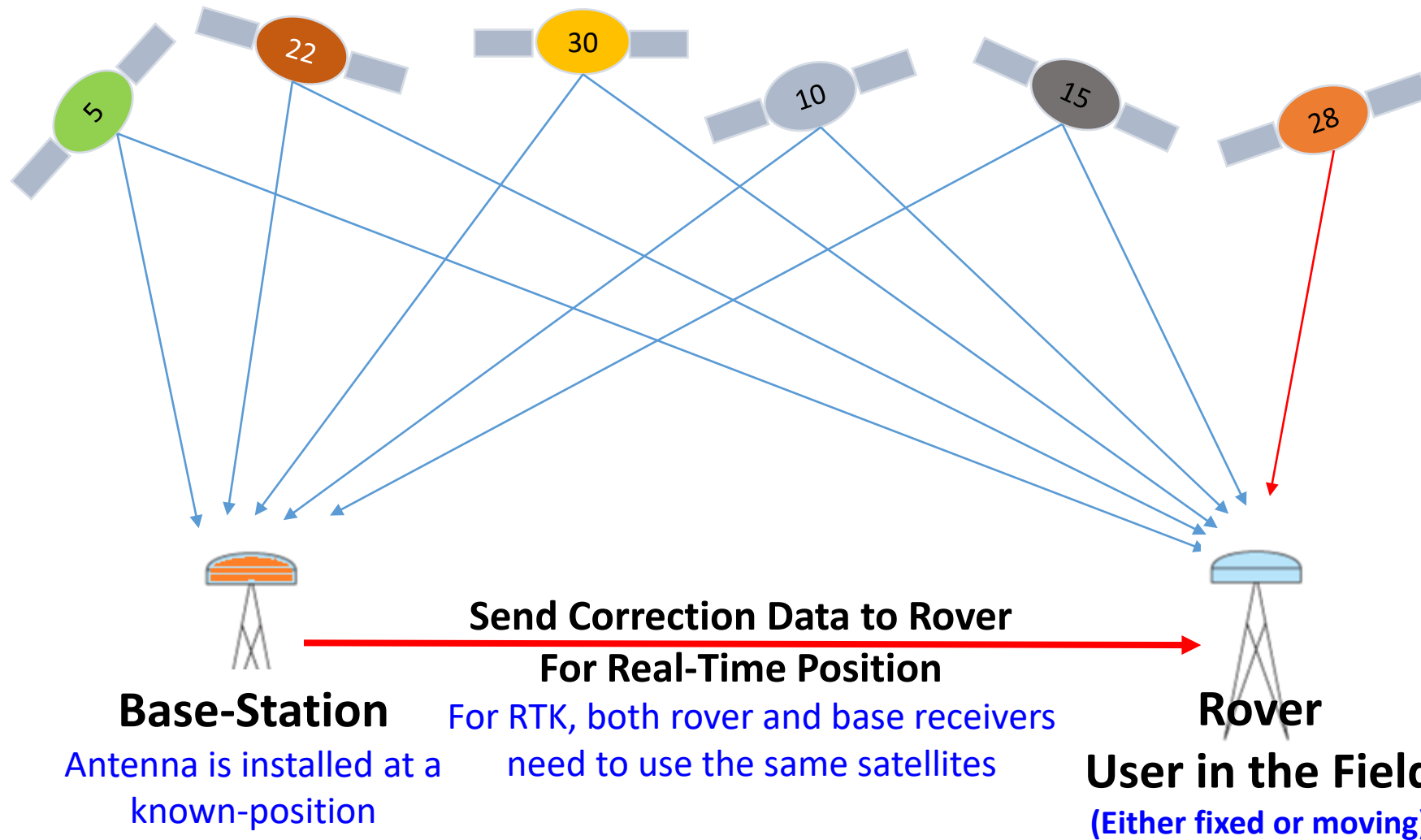
Principle of QZSS MADOCA and CLAS Services
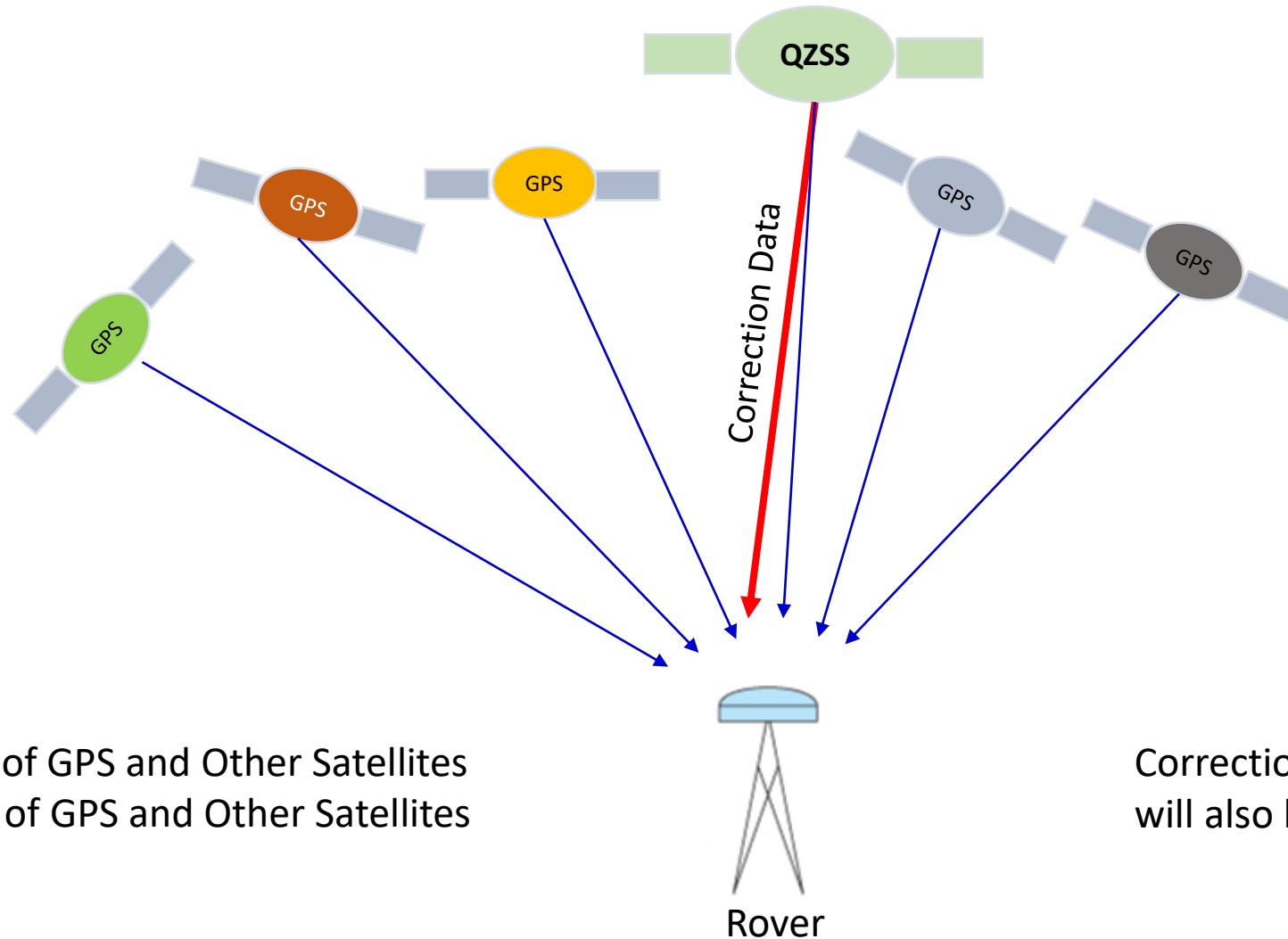
Correction Data:

Satellite Orbit Error of GPS and Other Satellites
Satellite Clock Error of GPS and Other Satellites

Correction data for other satellites
will also be provided

Rover

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Low-Cost High Accuracy System

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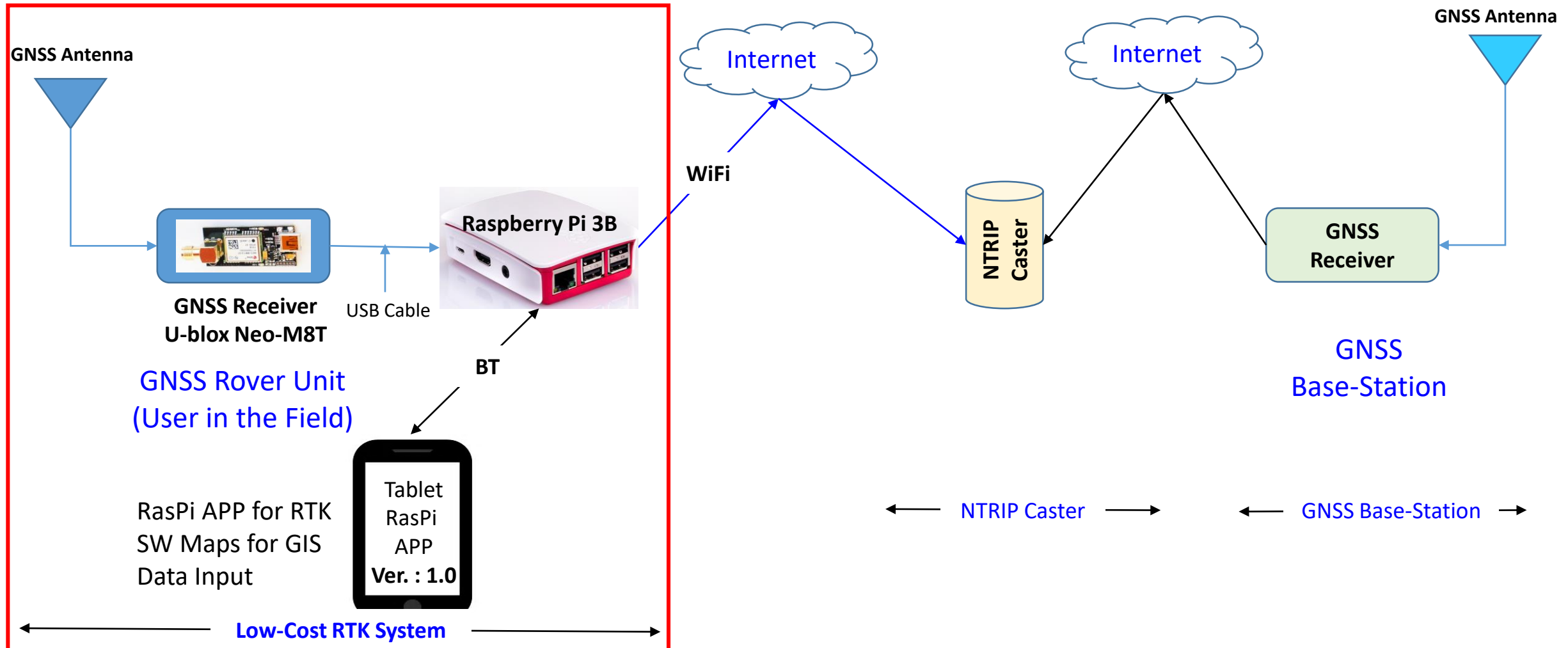
RTK-Pi APP for Low-Cost RTK System

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Board Computer for Low-Cost RTK System

Raspberry Pi 3B for Realtime and Postprocessing RTK

Raspberry Pi Zero w/WiFi & BT for Post-processing RTK

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Accuracy from Low-Cost RTK System
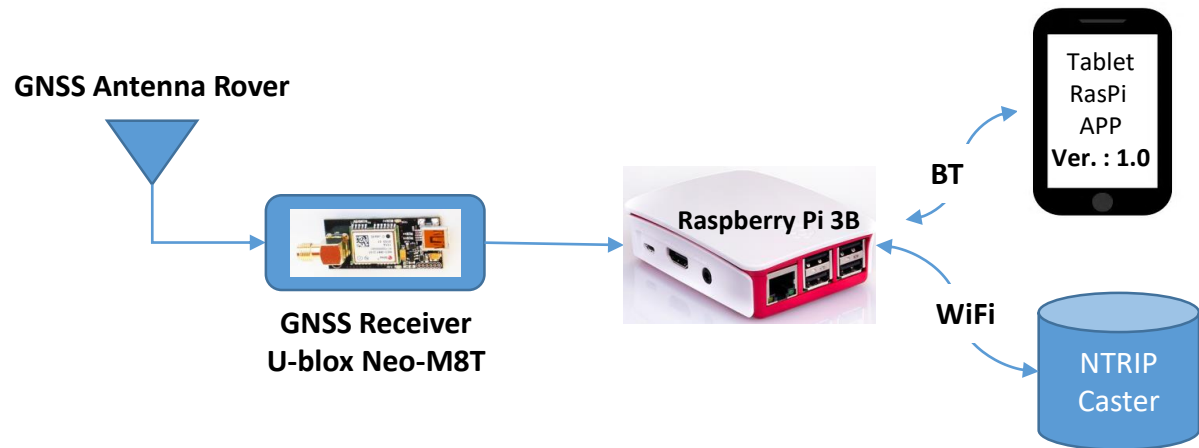
Rover-Station:

Receiver: u-blox M8T

Antenna: Zephyr 2

Computer: RaspberryPi 3B+

Distance between Base and Rover : about 12Km

Base-Station:

Receiver: Trimble NetR9

Antenna: Zephyr 2

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Data from Low-Cost RTK System

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Data from Low-Cost RTK System

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Simple to Use, Plug-And-Record, Low-Cost System Receiver

- Simple to Use, No Commands, Just One Time Setting

- Connect Antenna, Receiver and Battery Pack

- Device Starts Logging GNSS Raw Data required for RTK Post-Processing

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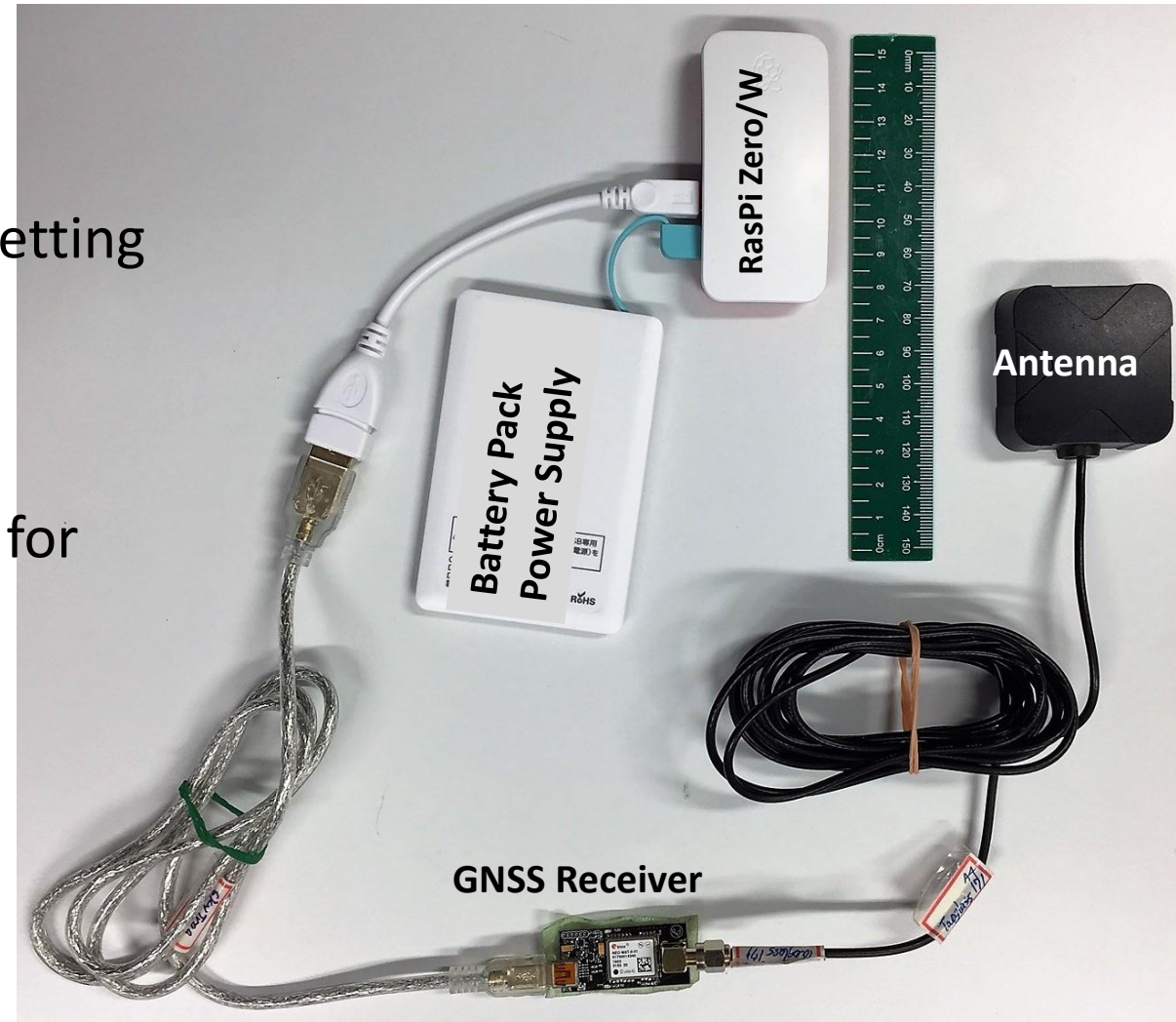
Conclusion

- Accuracy better than <u>few tens of centimeters</u> using Low-Cost Receiver in RTK mode is possible.
  - Both Base and Rover with Low-Cost Receiver
  - Smaller base length, < 10km

- Accuracy better than <u>few centimeters</u> using Low-Cost Receiver in RTK mode is possible.
  - Base with High-End Receiver and Low-Cost Receiver
  - Smaller base length, < 5km

- Our Target of Low-Cost High-Accuracy Receiver
  - $100x100cmx100gm (Cost- Accuracy-Weight)

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Additional Information

Please visit website at

http://www.csis.u-tokyo.ac.jp/~dinesh/

https://www.youtube.com/watch?v=JaicV8egzFo

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Sample Raw Data can be downloaded to Check Accuracy of RTK Processing
1. High-End Base (NetR9) Data vs Low-End Rover (u-blox M8T) Data
2. Low-End Base (u-blox M8T) Data vs Low-End Rover (u-Blox M8T) Data

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