GNSS Applications for Policy and Decision Makers in the Context of Nepal

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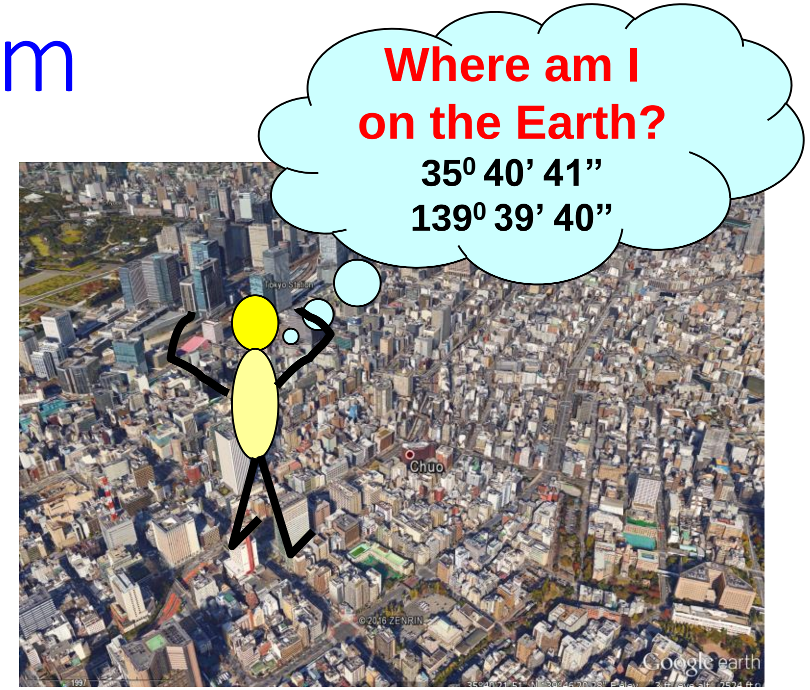
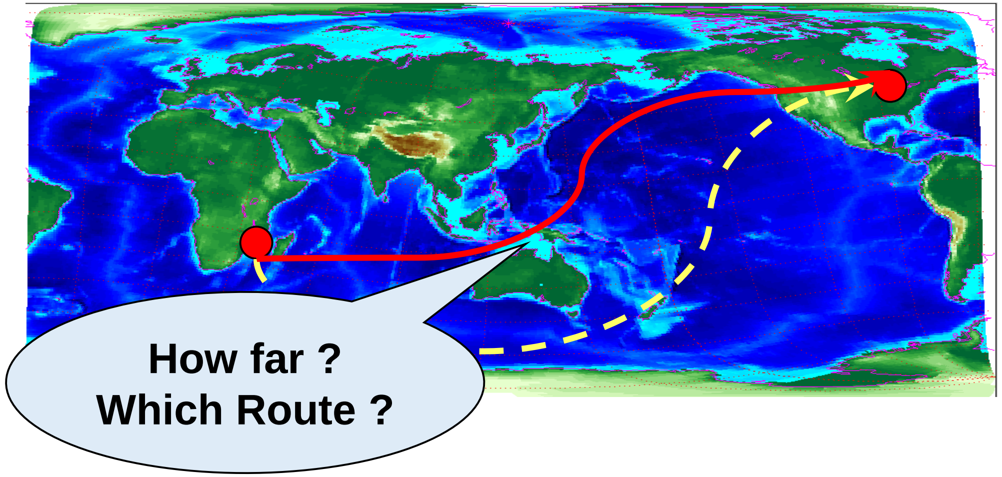
Fundamental Problem

- How to know my location precisely ?
  - In any condition
  - At any time
  - Everywhere on earth (at least outdoors!)
- How to navigate to the destination?
  - Guidance or Navigation
- How to synchronize time globally?
  - Mobile phones
  - Financial Institutes





Navigation Types

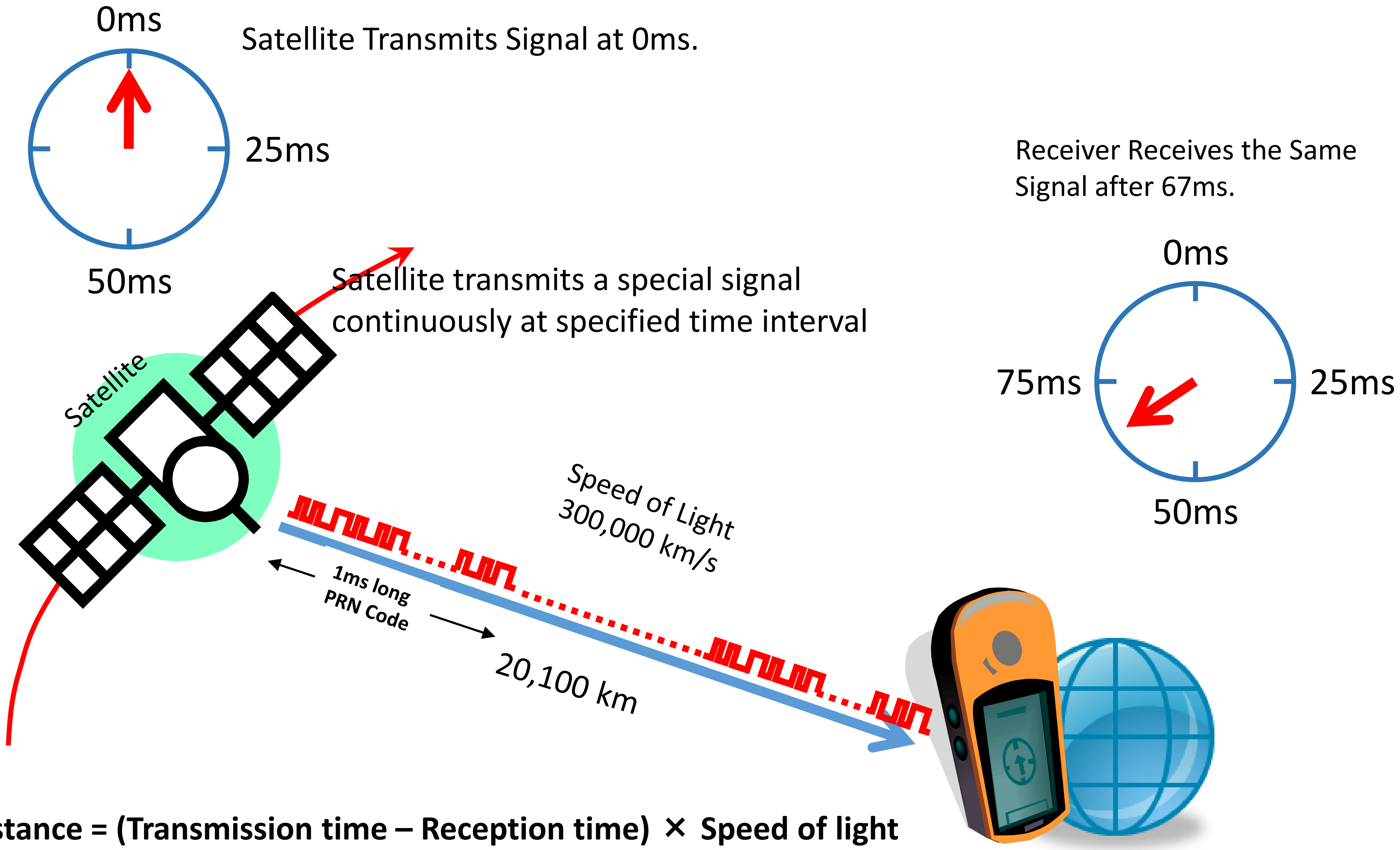
- Landmark-based Navigation
  - Stones, Trees, Monuments
    - Limited Local use
- Celestial-based Navigation
  - Stars, Moon
    - Complicated, Works only at Clear Night
- Sensors-based Navigation
  - Dead Reckoning
    - Gyroscope, Accelerometer, Compass, Odometer
    - Complicated, Errors accumulate quickly
- Radio-based Navigation
  - LORAN, OMEGA
    - Subject to Radio Interference, Jamming, Limited Coverage
- Satellite-based Navigation or GNSS
  - TRANSIT, GPS, GLONASS, GALILEO, QZSS, BEIDOU (COMPASS), IRNSS
    - Global, Difficult to Interfere or Jam, High Accuracy & Reliability

What is GNSS?

Global Navigation Satellite System (GNSS) is a generic term for all navigation satellite systems like GPS, GLONASS, GALILEO, BeiDou, QZSS and NAVIC.

- Global Constellation
  - GPS, USA
  - GLONASS, Russia
  - Galileo, Europe
  - BeiDou (COMPASS) / BDS, China
- Regional Constellation
  - QZSS, Japan
  - NAVIC (IRNSS), India

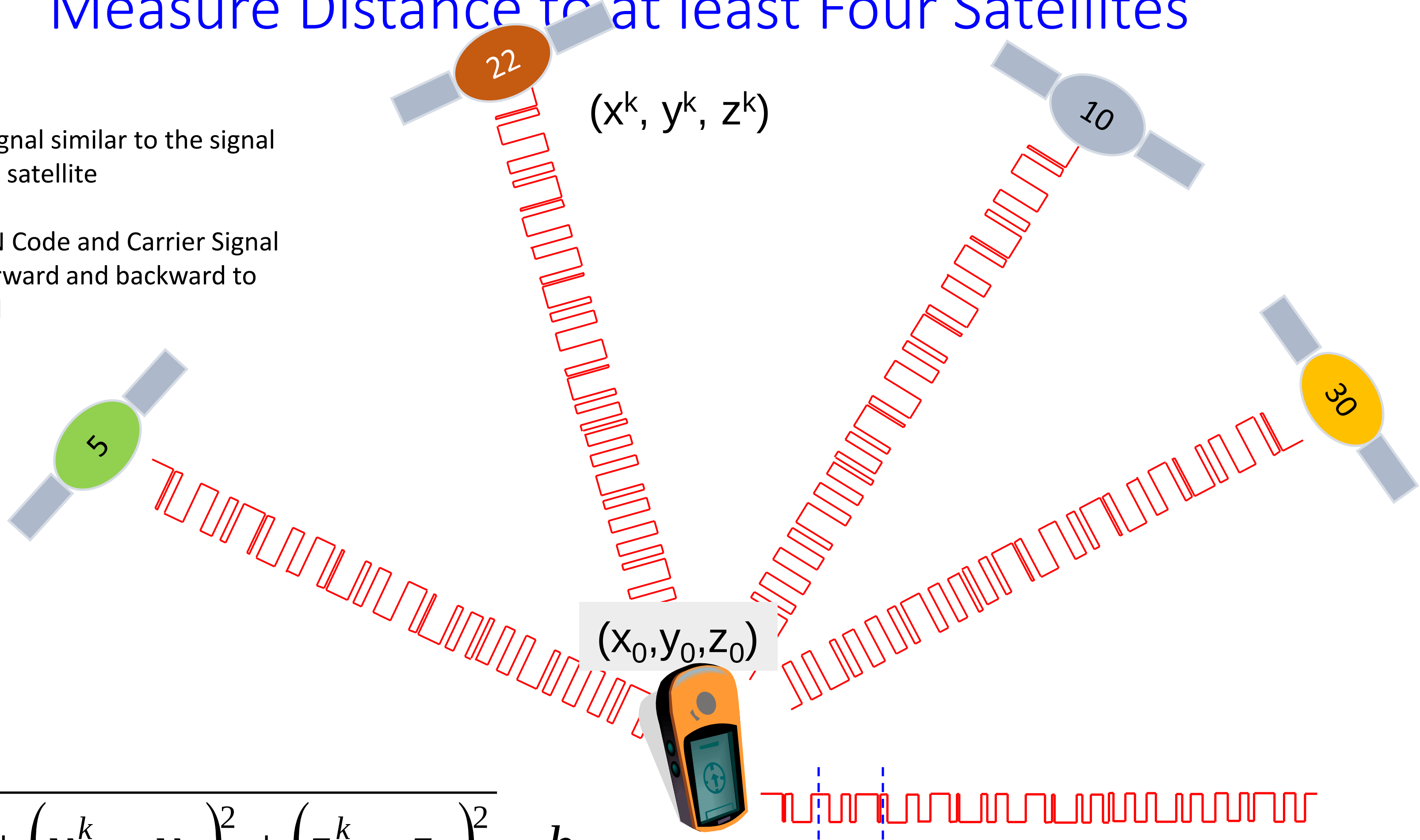
GNSS: How does it work?
Determine the Distance using Radio Wave



Distance = (Transmission time – Reception time) × Speed of light

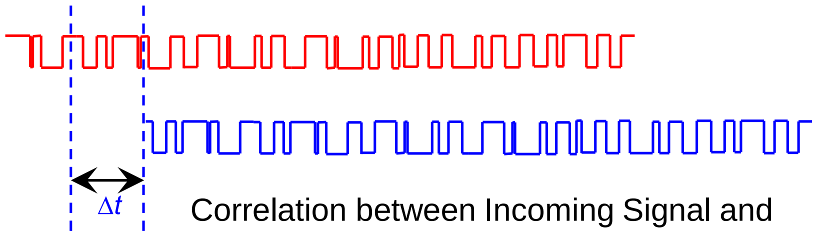
GNSS: How does it work?
Measure Distance to at least Four Satellites

Receiver generates its own GPS signal similar to the signal coming from the satellite for each satellite
- ➔ Its called Replica Signal
- ➔ The Replica Signal includes PRN Code and Carrier Signal
- ➔ This Replica Signal is moved forward and backward to match with the incoming signal



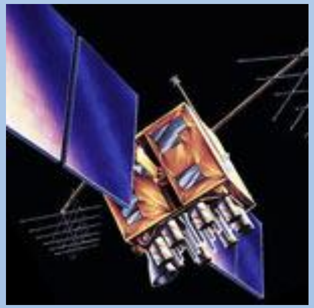
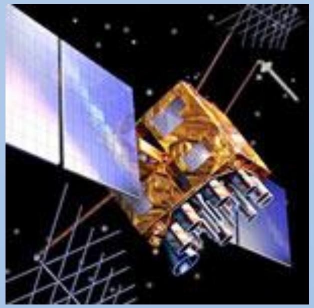
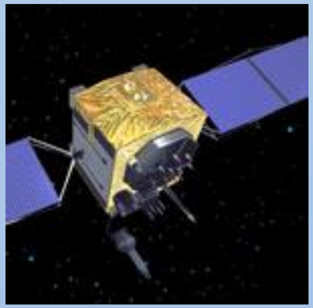
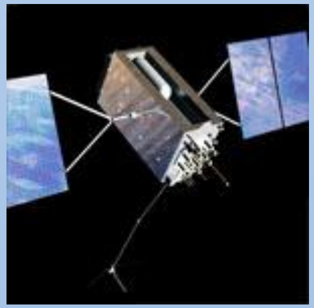
$$\rho^k = \sqrt{\left(x^k - x_0\right)^2 + \left(y^k - y_0\right)^2 + \left(z^k - z_0\right)^2} - b$$

If $k \geq 4$, solve for x, y, z and clock bias, b



Correlation between Incoming Signal and Receiver Generated Signal

GPS Space Segment: Current & Future Constellation

Legacy Satellites		Modernized Satellites		
				
Block IIA	**Block IIR**	**Block IIR(M)**	**Block IIF**	**GPS III**
0 operational	**9 operational**	**7 operational**	**12 operational**	**2 operational**
• Coarse Acquisition (C/A) code on L1 frequency for civil users • Precise P(Y) code on L1 & L2 frequencies for military users • 7.5-year design lifespan • Launched in 1990-1997 • Last one decommissioned in 2019	• C/A code on L1 • P(Y) code on L1 & L2 • On-board clock monitoring • 7.5-year design lifespan • Launched in 1997-2004	• All legacy signals • 2nd civil signal on L2 (L2C) • New military M code signals for enhanced jam resistance • Flexible power levels for military signals • 7.5-year design lifespan • Launched in 2005-2009	• All Block IIR-M signals • 3rd civil signal on L5 frequency (L5) • Advanced atomic clocks • Improved accuracy, signal strength, and quality • 12-year design lifespan • Launched in 2010-2016	• All Block IIF signals • 4th civil signal on L1 (L1C) • Enhanced signal reliability, accuracy, and integrity • No Selective Availability • 15-year design lifespan • IIIF: laser reflectors; search & rescue payload • First launch in 2018

Source: http://www.gps.gov/systems/gps/space/#IIF
https://www.unoosa.org/oosa/en/ourwork/icg/annual-meetings

Information in this slide may not be the latest information.
Please check the Source HP link and UNOOSA documents

GLONASS (Russia)

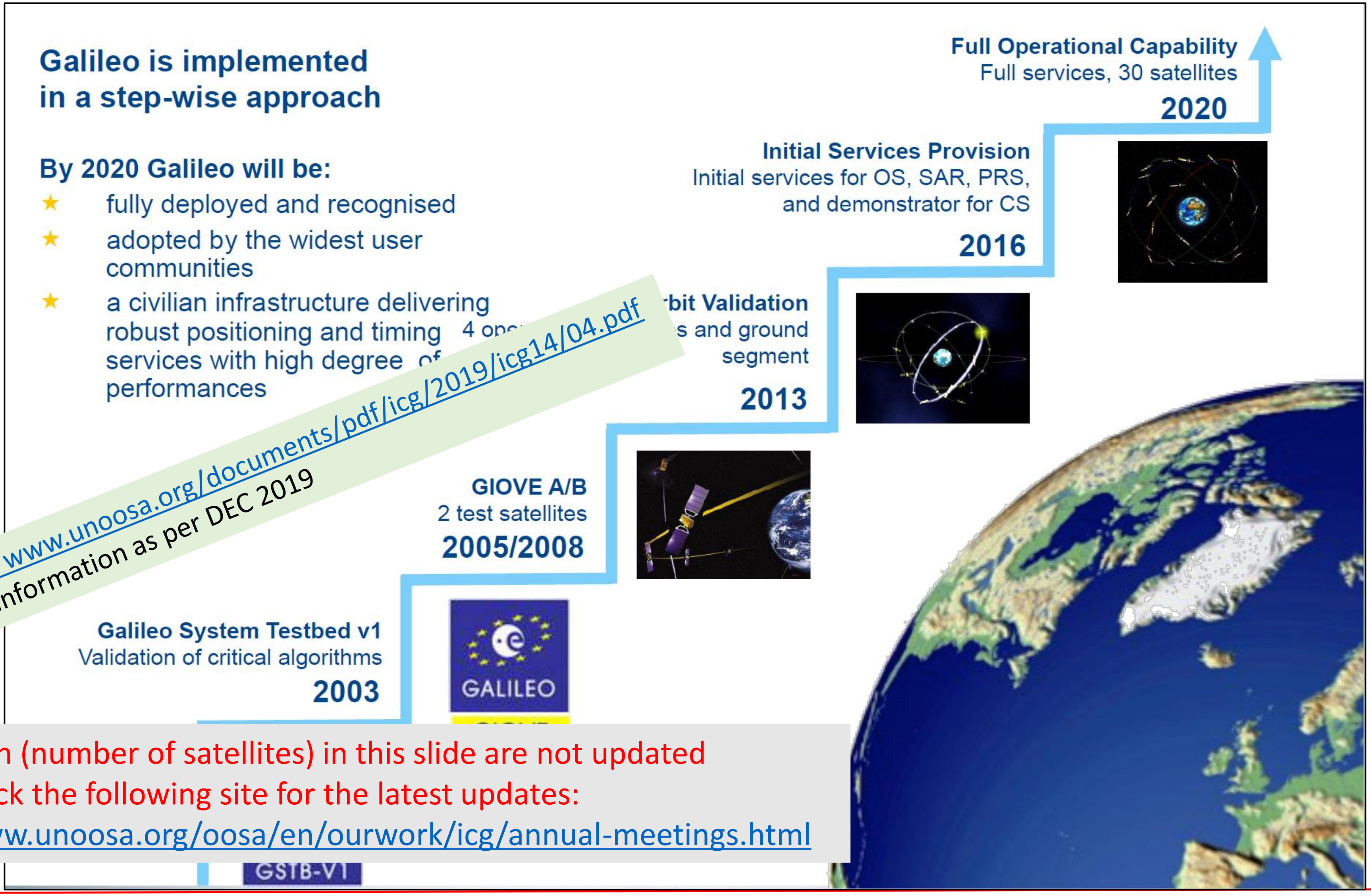
1982 First Launch	2003	2011	Planned Launch
			
GLONASS	GLONASS-M	GLONASS-K1	GLONASS-K2
DECOMMISSIONED 87 Launched 0 Operational 81 Retired 6 Lost	Under Normal Operation 45 Launched 27 Operational 12 Retired 6 Lost	Under Production / Operation 2 Launched 2 Operational First launch	d 2018
•L1OF, L1SF • L2SF	•L1OF, L1SF •L2OF, L2S •L3OC		L1OF, L1SF •L2OF, L2SF •L1OC, L1SC •L2OC, L2SC •L3OC

See File
https://www.unoosa.org/documents/pdf/icg/2019/icg14/03.pdf
for the latest information as per DEC 2019

Information (Number of Satellites) in this slide are not updated
Please check the following site for the latest updates:
https://www.unoosa.org/oosa/en/ourwork/icg/annual-meetings.html

GLONASS space segment STATUS & MODERNIZATION, Joint - Stock Company «Academician M.F. Reshetnev» Information Satellite Systems»
ICG-7, November 04-09, 2012 , Beijing, China, https://en.wikipedia.org/wiki/GLONASS-K2

Galileo (Europe)

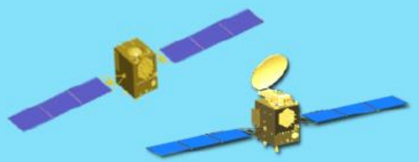


See file https://www.unoosa.org/documents/pdf/icg/2019/icg14/04.pdf
for the latest information as per DEC 2019

Information (number of satellites) in this slide are not updated
Please check the following site for the latest updates:
https://www.unoosa.org/oosa/en/ourwork/icg/annual-meetings.html

BeiDou Space Segment

Space Segment



- 5 GEO satellites
- 3 IGSO satellites
- 27 MEO satellites

Ground Segment

- Master Control Stations (MCS)
- Uplink Stations (US)
- Monitoring Stations (MS)

User Segment

- BeiDou terminals
- Terminals compatible with other navigation satellite systems

Four types of services:

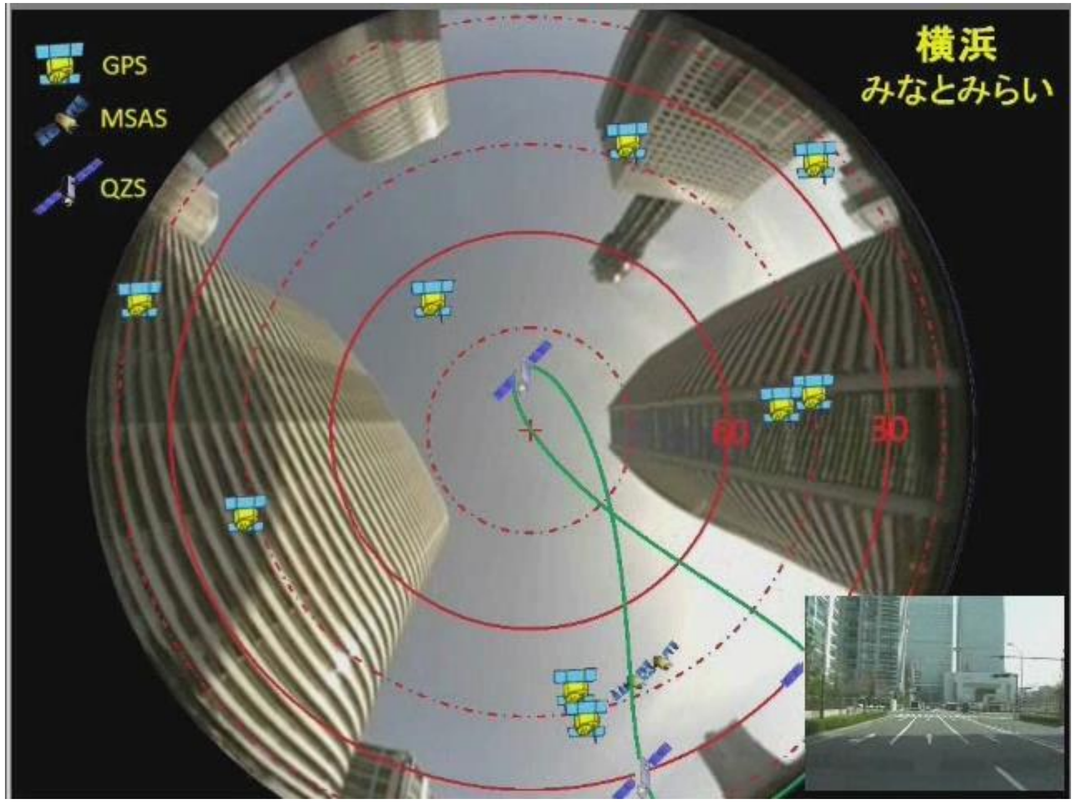
open, authorized, differential augmentation, and short message services.

The nominal positioning accuracy is better than 10 m, timing and velocity accuracy is better than 20 ns and 0.2 m/s respectively.

Information (number of satellites) in this slide are not updated
Please check the following site for the latest updates:
https://www.unoosa.org/documents/pdf/icg/2019/icg14/05.pdf

Source: Update on BeiDou Navigation Satellite System, Chengqi Ran, China Satellite Navigation Office
Tenth Meeting of ICG, NOV 2015

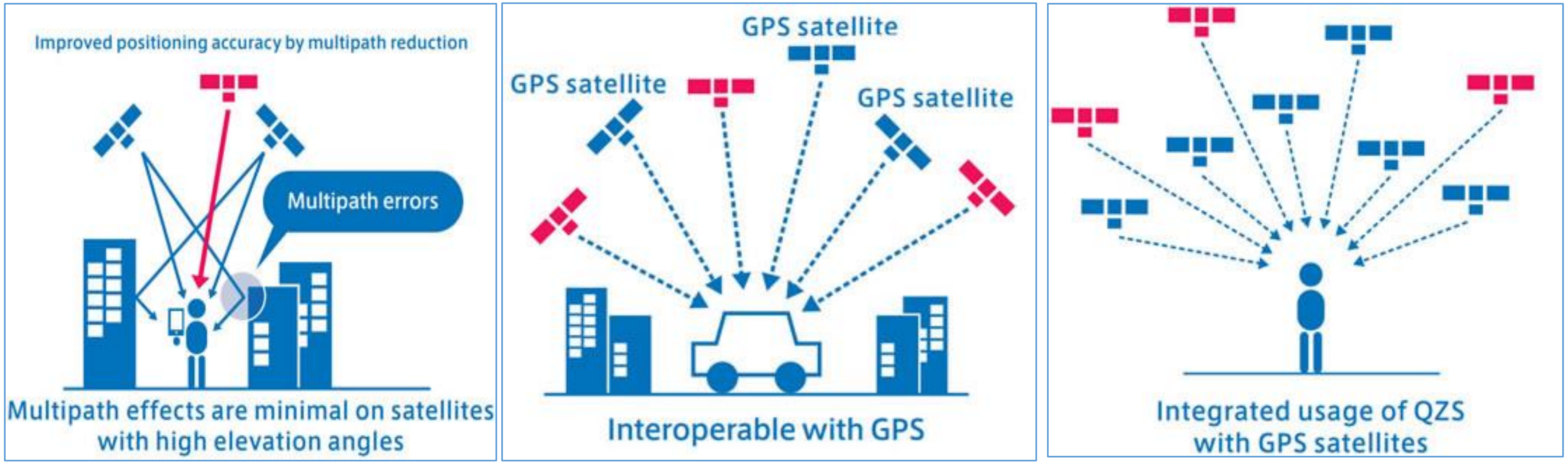
QZSS (Quasi-Zenith Satellite System)
Nickname: MICHIBIKI



Please check the document for the latest updates:

1. https://qzss.go.jp/en/ (Main Page)
2. https://qzss.go.jp/en/overview/downloads/movie_qzss.html (QZSS Movie)
3. https://www.unoosa.org/documents/pdf/icg/2019/icg14/06.pdf

Merits of QZSS

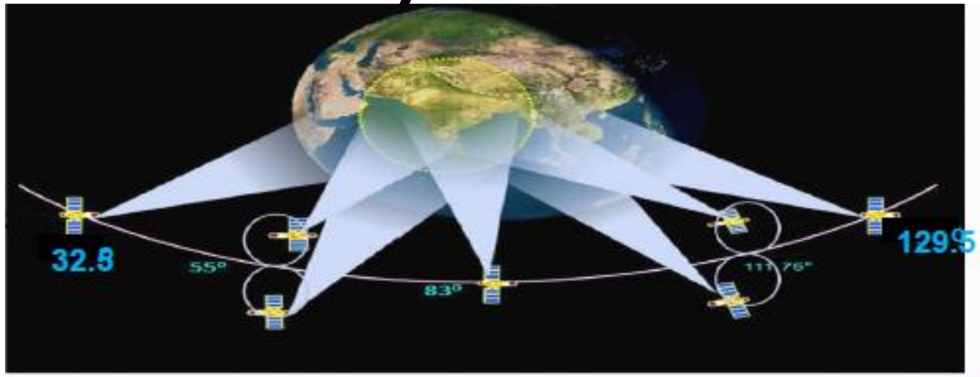


- QZSS signal is designed in such a way that it is **interoperable with GPS**
- QZSS is visible near zenith; improves visibility & DOP in dense urban area
- Provides Orbit Data of other GNSS signals
- Provides **Augmentation Data for Sub-meter and Centimeter level position accuracy**
- Provides Messaging System during Disasters

http://qzss.go.jp/en/overview/services/sv04_pnt.html

NavIC (Navigation with Indian Constellation)

- **Consists of 7 Satellites**
- **4 Geo Synchronous Orbit (GSO) satellites**
  - **at 55°E and 111.75°E at an inclination of 27°**
- **3 Geo Stationary Satellites (GEO)**
  - **at 32.5°E, 83°E and 129.5° E at an inclination of 5°**
- **Transmits signals in L5 band (1176.45MHz) and S band (2492.028MHz)**



Please check the following site for the latest updates:
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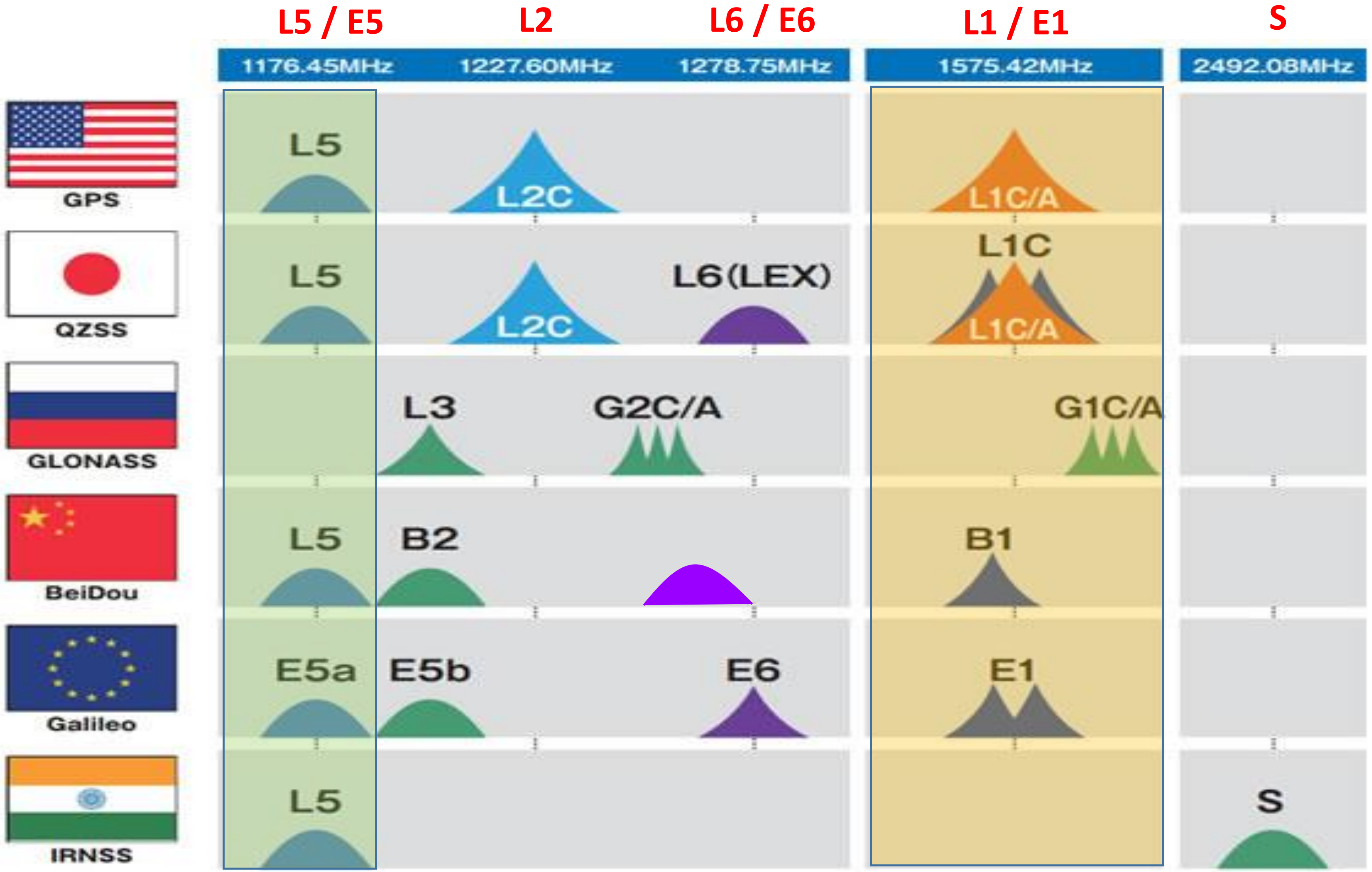
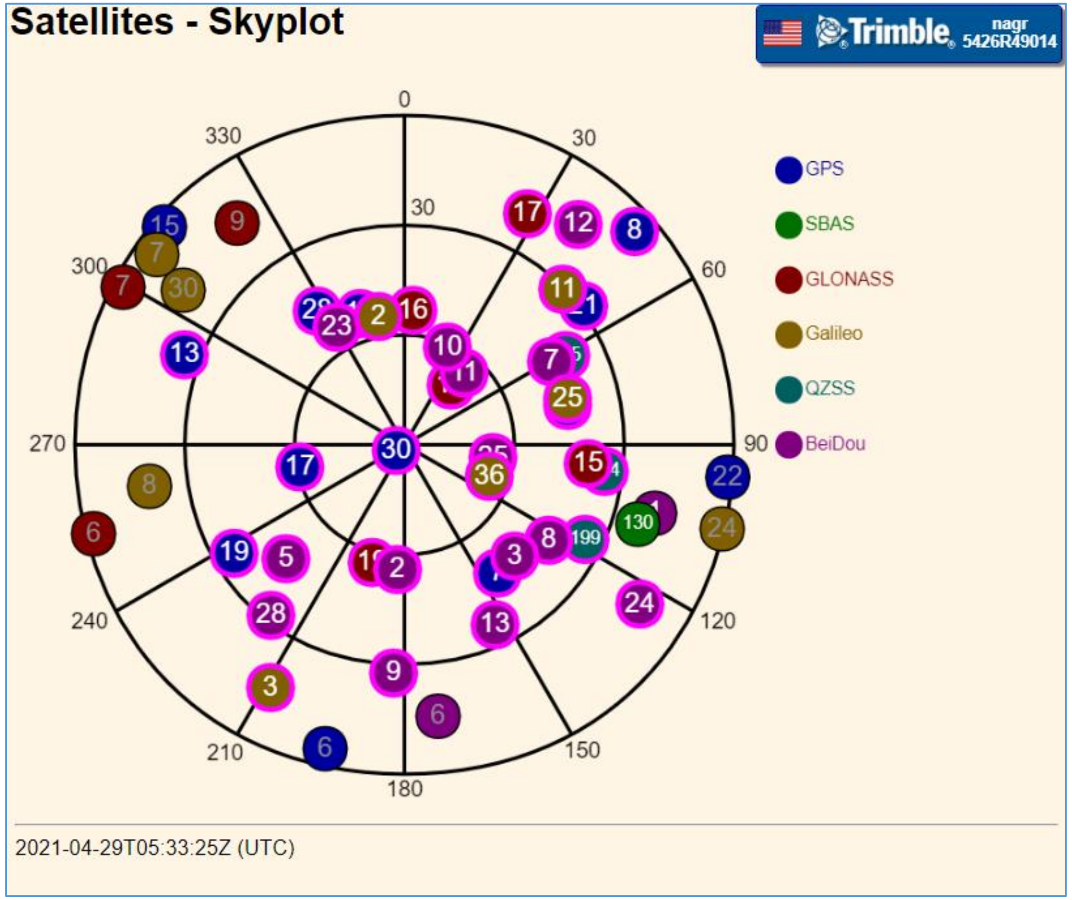
Multi-GNSS Signals



GNSS Visibility, Nagarkot Station



Position

Trimble nagr 5426R49014

Position:
Lat: 27° 41' 36.21219" N
Lon: 85° 31' 15.30999" E
Hgt: 2110.926 [m]
Type: Autonomous
Datum: WGS-84

Velocity:
East: -0.01 [m/s]
North: 0.00 [m/s]
Up: 0.00 [m/s]

Position Solution Detail:
Position Dimension: 3D
Augmentation: GPS+GLN+GAL+BDS+QZSS
Height Mode: Normal
Correction Controls: Off

Receiver Clock:
GPS Week: 2155
GPS Seconds: 365584
Offset: 0.00000 [msec]
Drift: 0.00000 [ppm]

Multi-System Clock Offsets:
Master Clock System: GPS
GLONASS Offset: -9.9 [ns]
Galileo Offset: 8.6 [ns]
BeiDou Offset: -30.3 [ns]
GLONASS Drift: 0.009 [ns/s]
Galileo Drift: 0.003 [ns/s]
BeiDou Drift: 0.030 [ns/s]

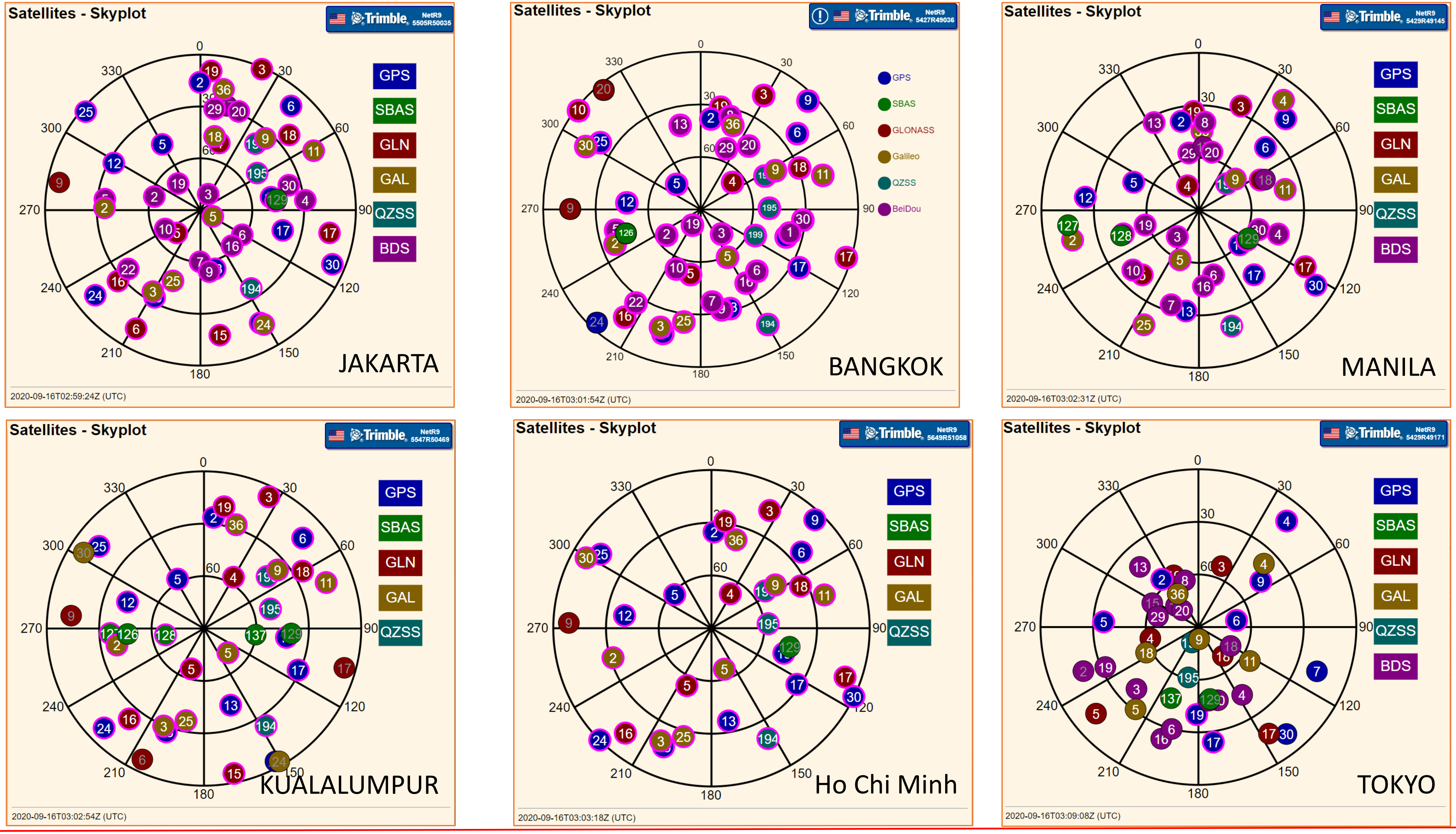
Satellites Used:37
GPS(10): 1, 7, 8, 13, 14, 17, 19, 21, 28, 30
GLONASS(5): 15, 16, 17, 18, 19
Galileo(5): 2, 3, 11, 25, 36
BeiDou(14): 2, 3, 5, 7, 8, 9, 10, 11, 12, 13, 23, 24, 25, 28
QZSS(3): 194, 195, 199

Satellites Tracked:40
GPS (10): 1, 7, 8, 13, 14, 17, 19, 21, 28, 30
GLONASS (5): 15, 16, 17, 18, 19
Galileo (5): 2, 3, 11, 25, 36
BeiDou (15): 1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13, 23, 24, 25, 28
SBAS (2): 130, 144
QZSS (3): 194, 195, 199

Dilutions of Precision:
PDOP: 0.9
HDOP: 0.5
VDOP: 0.8
TDOP: 0.6

Error Estimates(1σ):
East: 0.292 [m]
North: 0.324 [m]
Up: 0.819 [m]
Semi Major Axis: 0.331 [m]
Semi Minor Axis: 0.285 [m]
Orientation: 156.8°

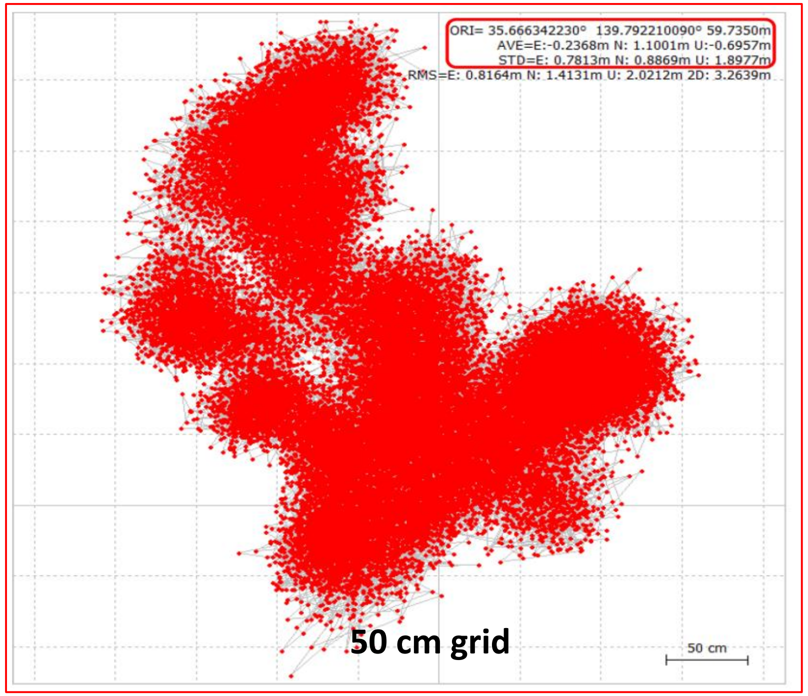
2021-04-29T05:32:46Z (UTC)


Satellites - Skyplot
JAKARTA
2020-09-16T02:59:24Z (UTC)
Satellites - Skyplot
BANGKOK
2020-09-16T03:01:54Z (UTC)
Satellites - Skyplot
MANILA
2020-09-16T03:02:31Z (UTC)
Satellites - Skyplot
KUALALUMPUR
2020-09-16T03:02:54Z (UTC)
Satellites - Skyplot
Ho Chi Minh
2020-09-16T03:03:18Z (UTC)
Satellites - Skyplot
TOKYO
2020-09-16T03:09:08Z (UTC)
GPS
SBAS
GLN
GAL
QZSS
BDS
GLONASS
Galileo
BeiDou

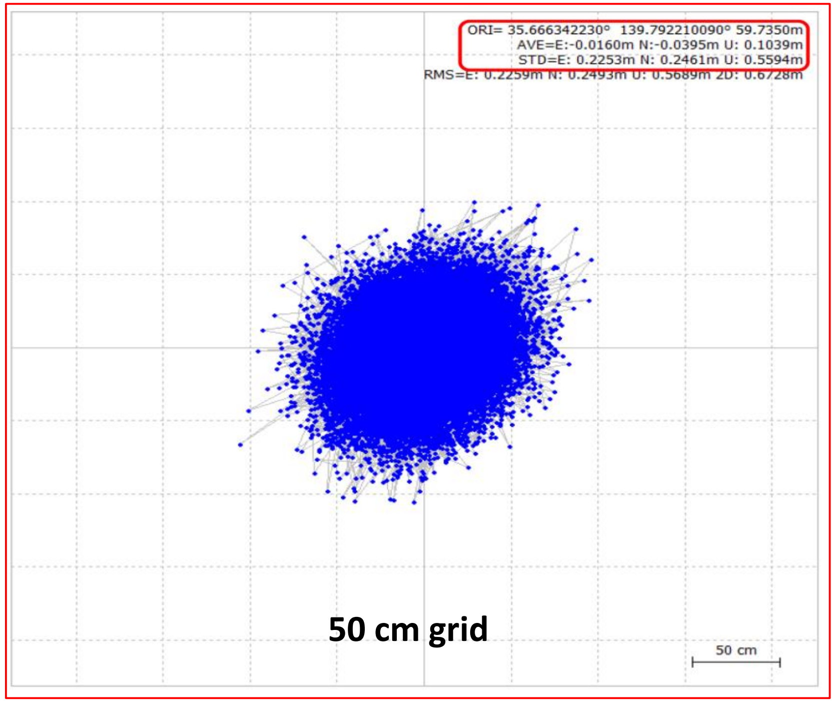
GPS Position Accuracy

How to achieve accuracy from few meters to few centimeters?

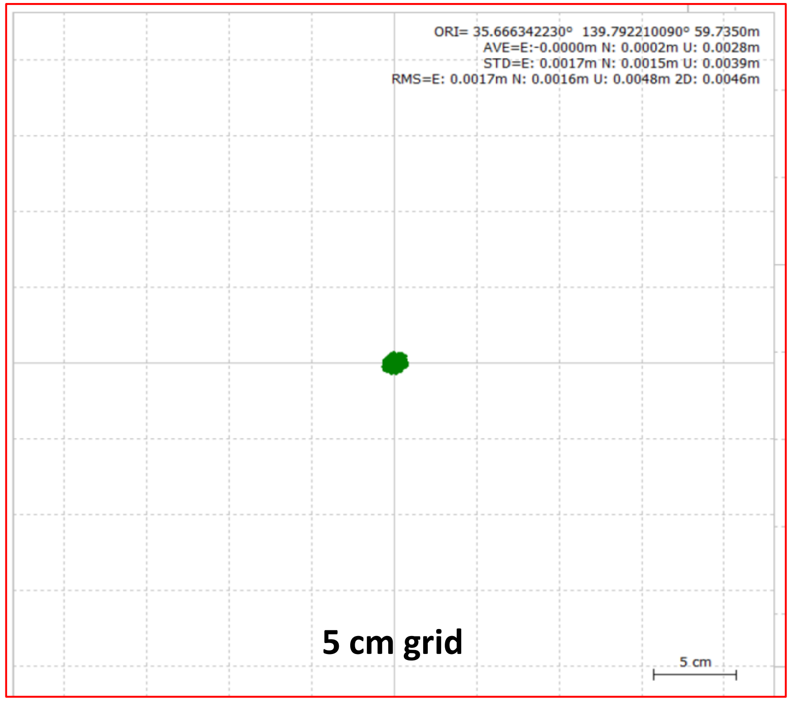
meter → centimeter



SPP (Single Point Position)



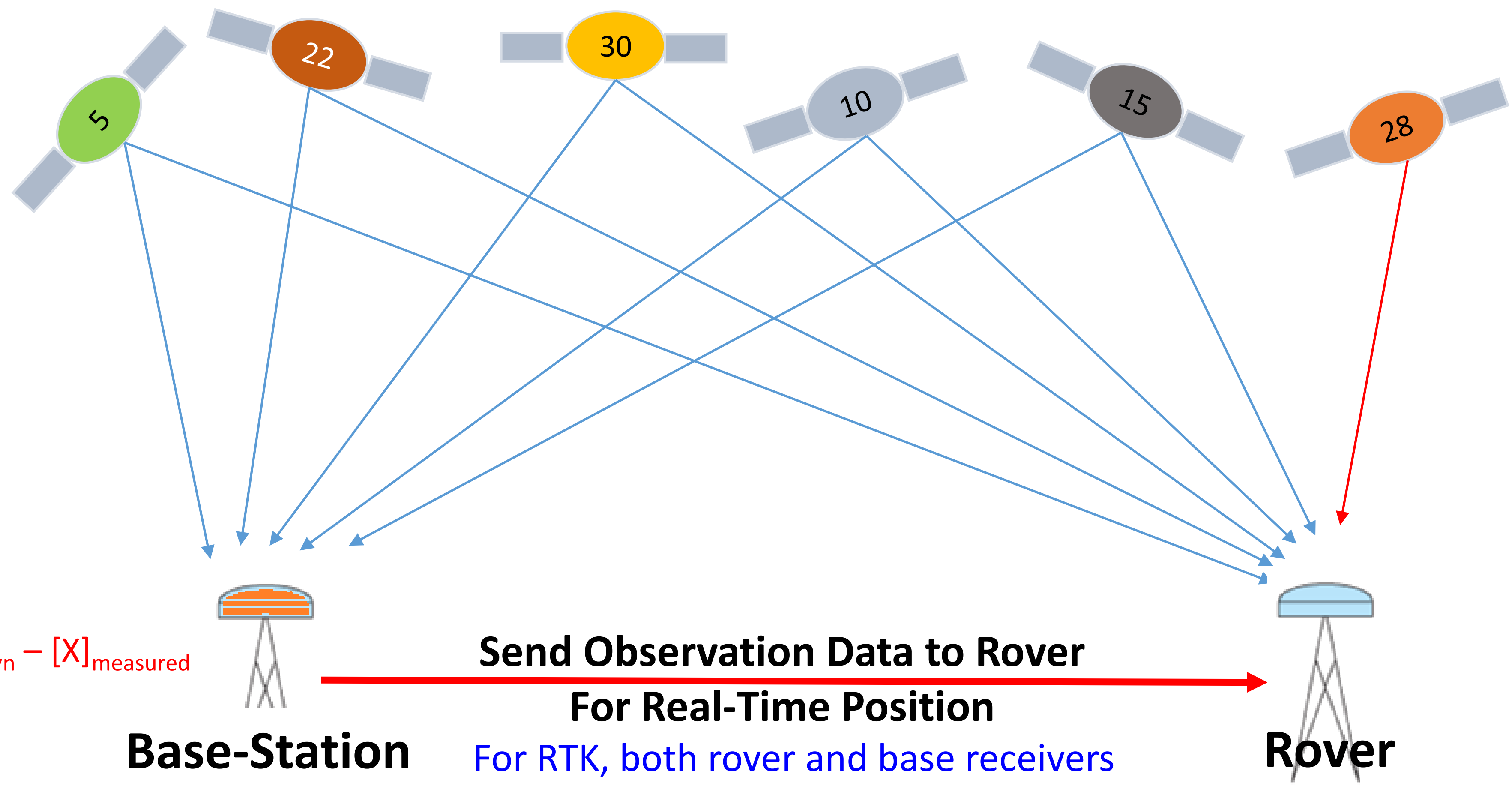
DGPS (Differential GPS)
Code-phase observation



RTK (Real Time Kinematic)
Carrier-phase observation

How to Remove or Minimize Common Errors?

Use Differential Correction



$[X]_{error} = [X]_{known} - [X]_{measured}$

Send Observation 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

Base-station Antenna position shall be known in advance

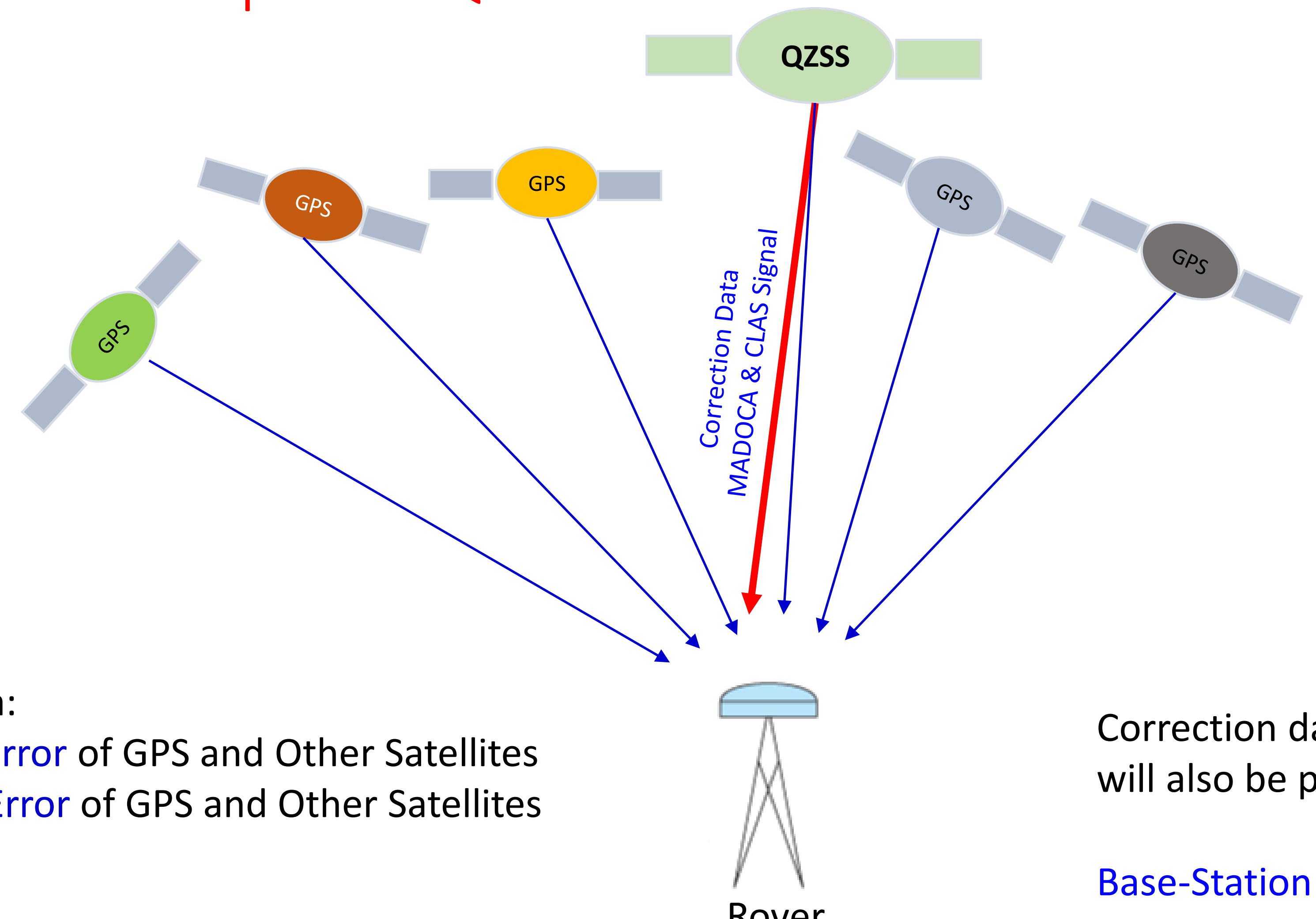
Rover

User in the Field

(Either fixed or moving)

How to Remove or Minimize Common Errors?

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

Base-Station not required

Low-Cost Receiver Systems

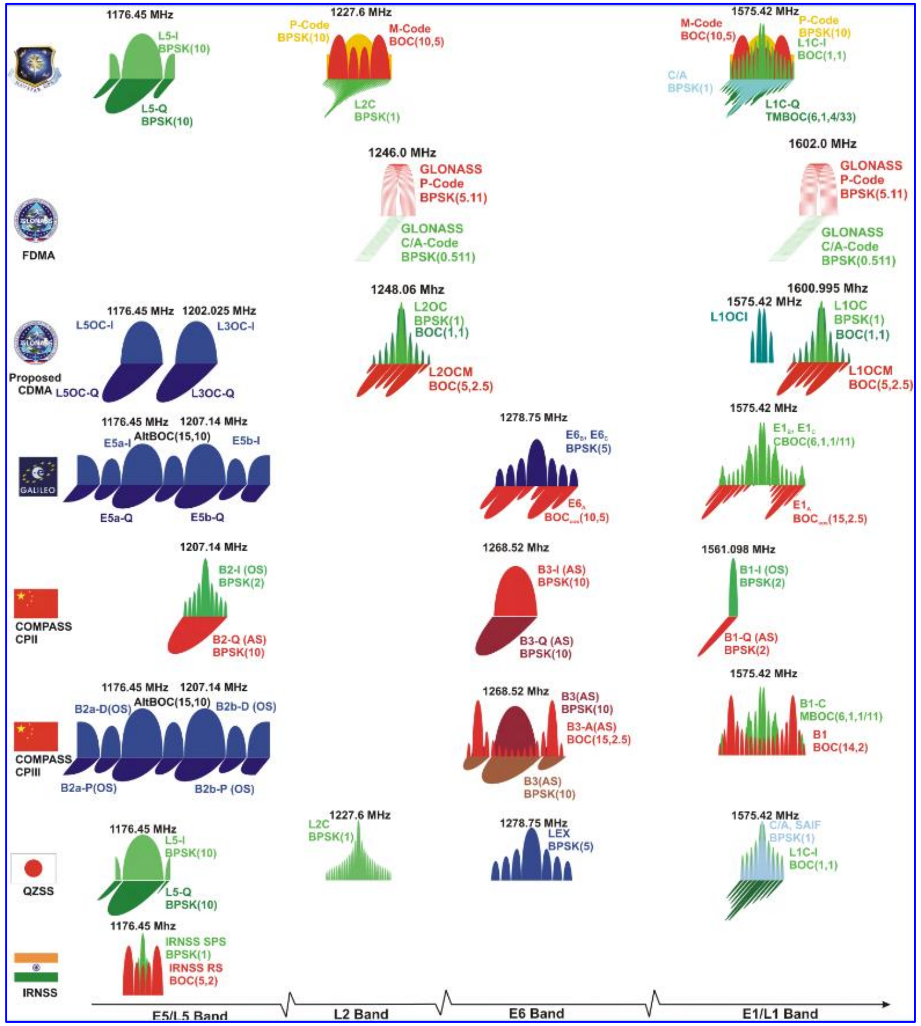
Quiz

- What is the Price of a GNSS Receiver?
  - $10? / $100? / $500 / $1,000 / $3,000 / $10,000 or more?
- What is the Accuracy that you can get from a GNSS receiver?
  - mm, cm, dm, few meters or 10 – 30m
- But, what are your requirements?
  - Types of Applications
  - Accuracy Requirements
  - Data Logging Methods
    - Static Mode (on a Tripod)
    - Dynamic Mode on Vehicle, Tractor or Machine?
  - Real-Time or Post-Processing

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

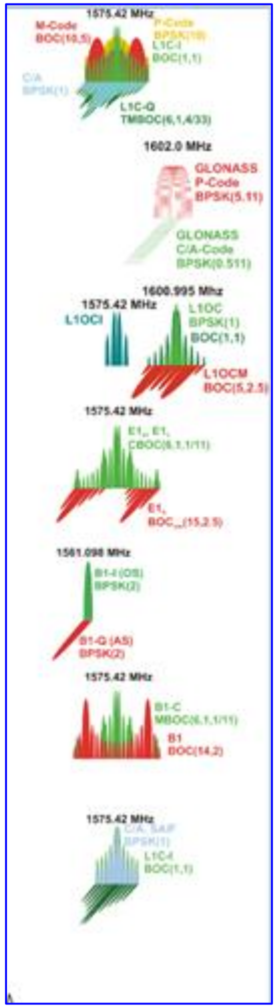
L5/E5/B2/L3 L2 L6/E6/B3 L1/E1/B1



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 $300 (Multi-GNSS, L1 Only) including Antenna and all necessary Hardware, Software
    - Our target is within $100 or less including everything

L1/E1/B1*



*Note: Only one signal type from each system is processed
e.g. GPS has L1C/A and L1C in L1, ,but only L1C/A is used in Low-Cost Receiver

Center for Spatial Information Science
The University of Tokyo

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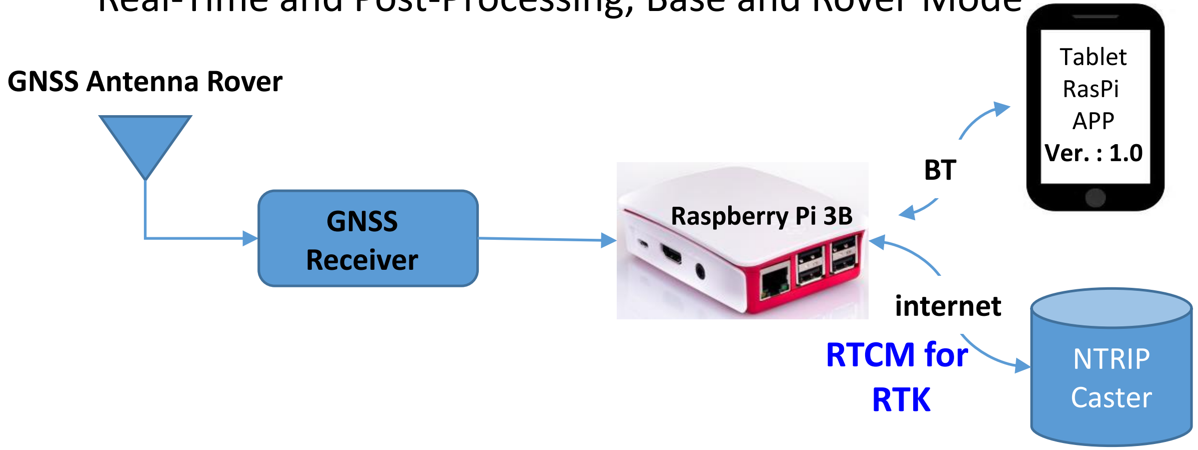
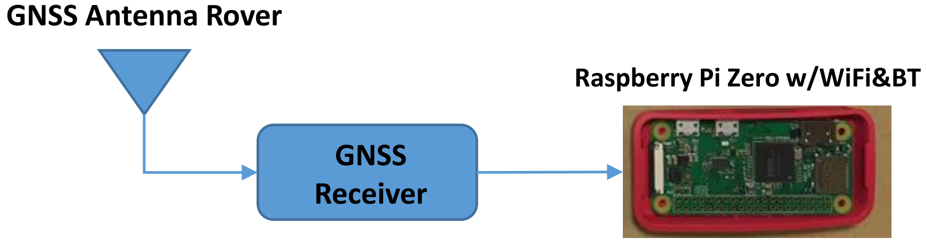
Low-Cost RTK Receiver System

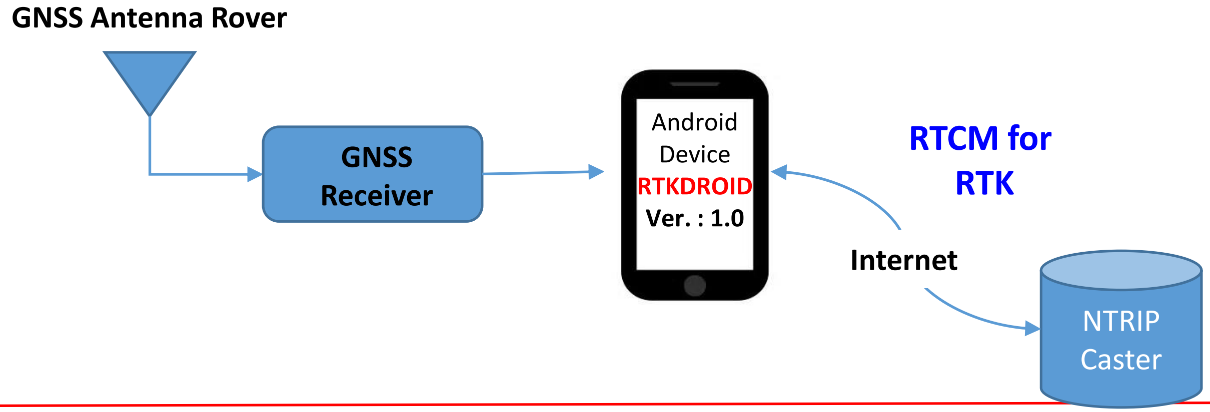
TYPE R1 Type A: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Base and Rover Mode



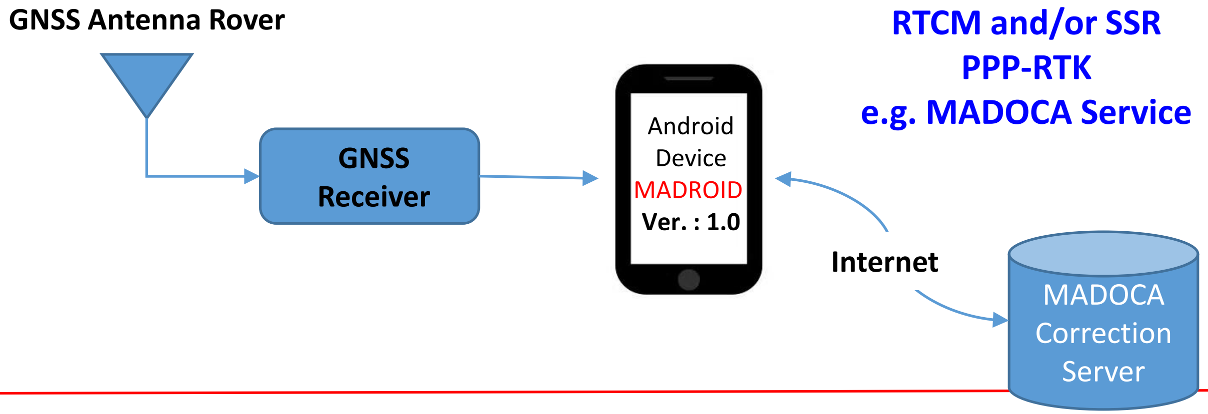
TYPE R2 Type B: Low-Cost, High-Accuracy Receiver System
For Post-Processing & Rover Mode Only



TYPE A1 Type C: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only



TYPE MA Type D: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only

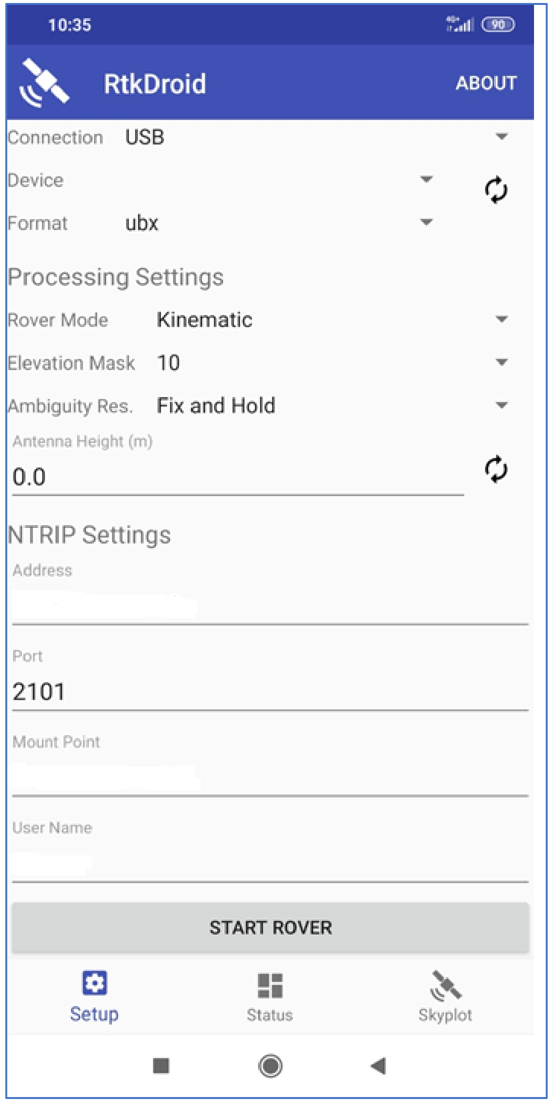


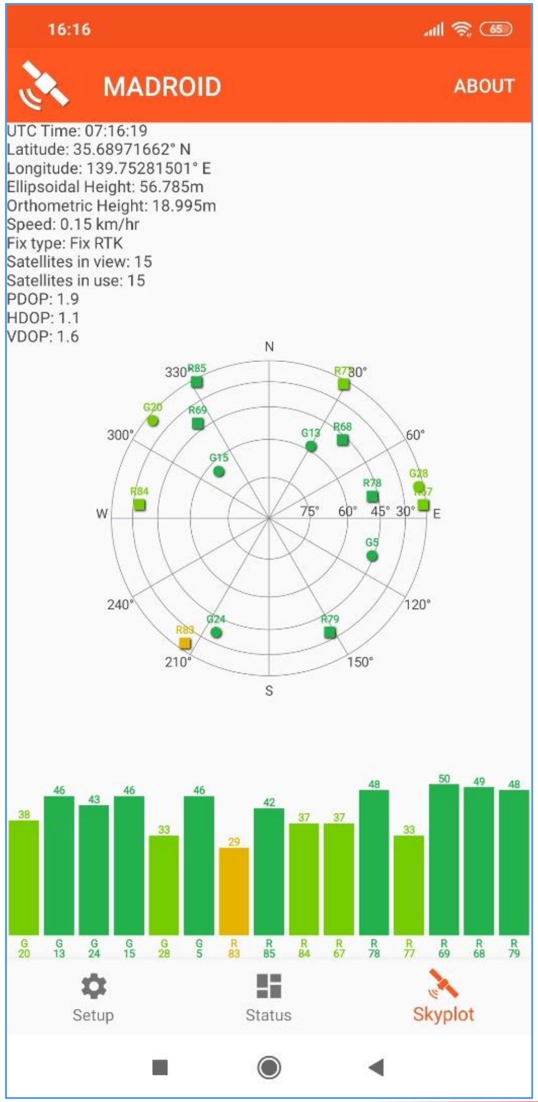
Screen Shots of RTKDROID and MADROID

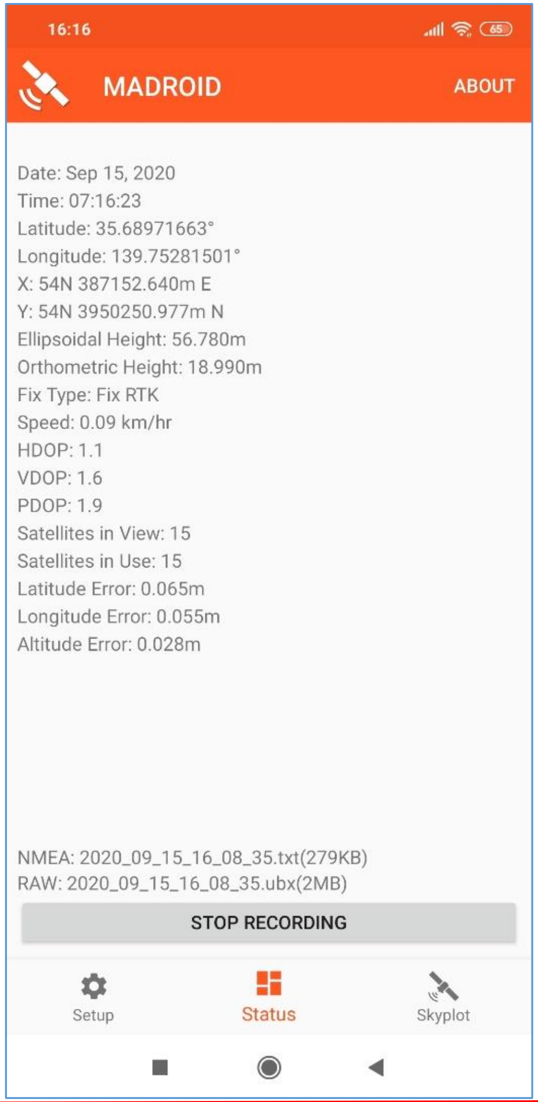
Connect GNSS receiver to Android device

(1) RTKDROID :
For RTK or PPK

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

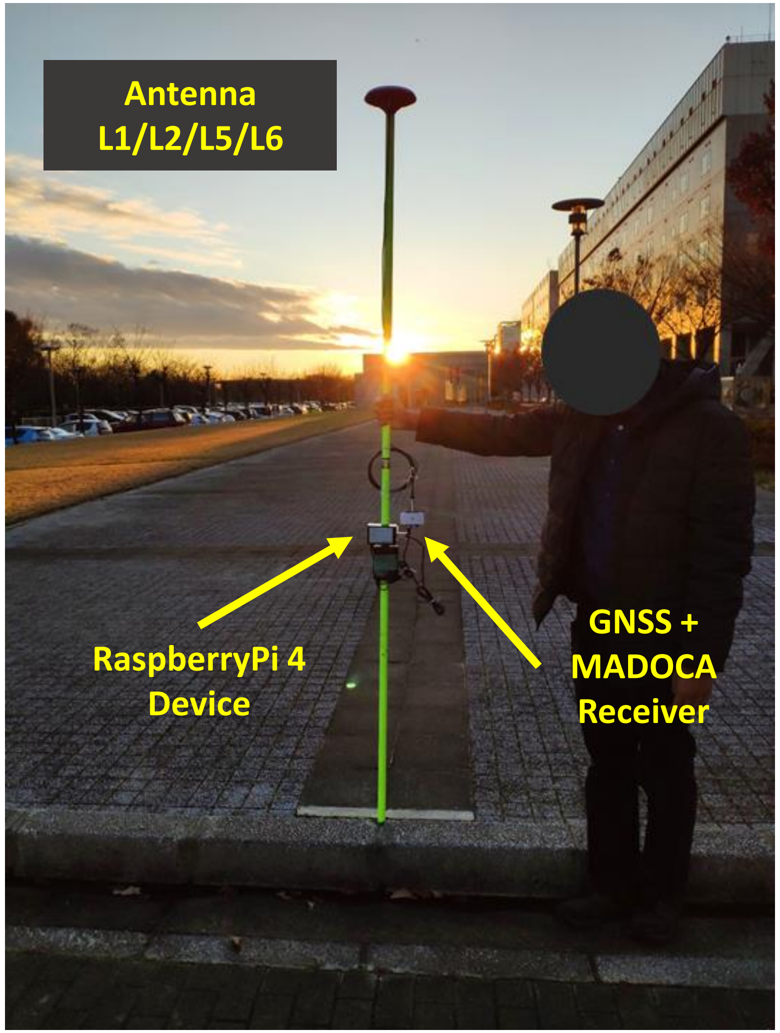






Type A: MAD-PI

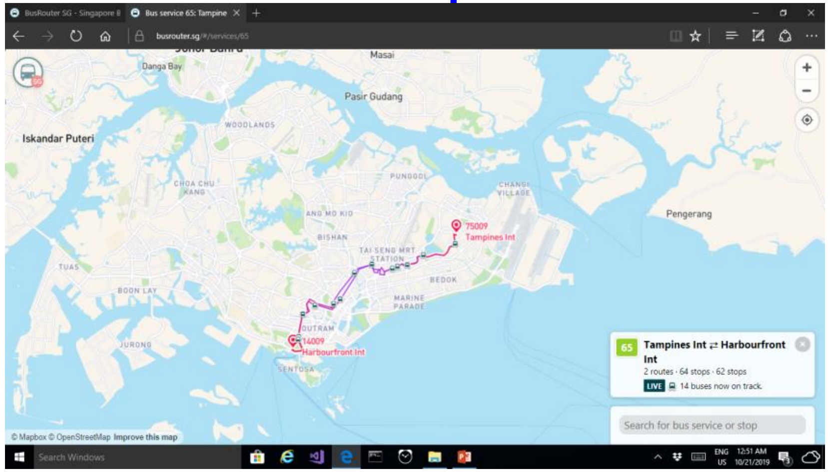
MADOCA PPP based on RaspberryPi / Dual Frequency Receiver + MADOCA Decoder

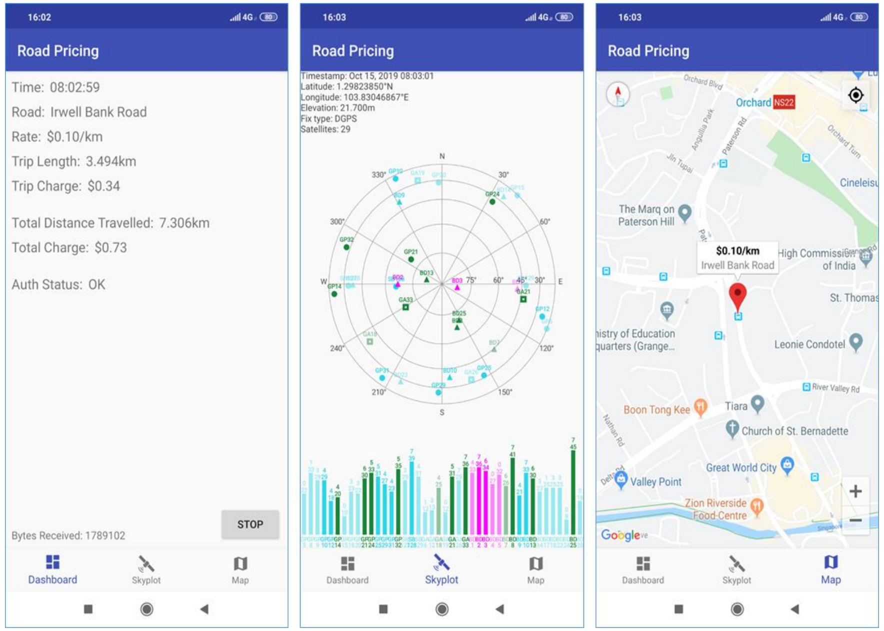


GNSS Applications

GNSS Applications in the Context of Nepal - 1

- Public Transport Monitoring
  - Necessary from safety and security reasons
  - Monitoring of taxis, buses, trucks, tankers and containers
  - Avoid or minimize accidents
  - Traffic congestion monitoring
  - Dynamic Road Pricing





GNSS Applications in the Context of Nepal - 2

- Early Warning System and Disaster Management
  - Provide early warning to public immediately
  - Provide guidance based on user's location
- Nepal is prone to several natural disasters
  - Shall have EWS that works even when mobile phone networks do not work
  - QZSS EWS is one of the suitable systems
- Land-slide and Flood Monitoring
  - GPS based sensors can be used for monitoring
  - Glacier monitoring

https://qzss.go.jp/en/overview/services/sv08_dc-report.html

GNSS Applications in the Context of Nepal - 3

- GNSS CORS Network
  - CORS: Continuously Observing Reference Station
  - Necessary to provide high-accuracy positioning services such as
    - Surveying and Mapping
      - Border mapping, Everest height measurement, infrastructure mapping, GIS
    - DGPS, RTK Services to users
    - Monitor land movement for Earthquake prediction and monitoring
    - Ionosphere and Troposphere monitoring
    - Time related services
      - How is time related services provided in Nepal?
    - Scientific research

GNSS Applications in the Context of Nepal - 4

- Infrastructure Planning and Monitoring
  - Minimize field survey work dramatically
    - Site survey for road, tunnel, bridge, dam, transmission line construction
    - Direct geo-referencing of drone image data
- Huge Infrastructure Monitoring
  - Monitoring of bridges and dams

GNSS Applications in the Context of Nepal - 5

- Tourism and Trekking
  - Provide location based services to tourists and trekkers
  - Fast Search-And-Rescue (SAR) during emergencies
    - Important at high-altitudes
  - Monitoring and guidance to trekkers as well as liaison officers
  - Enforce Geo-Fence or entry to protected areas

GNSS Applications in the Context of Nepal - 6

- High-Altitude and Scientific Experiments
  - Nepal is among the best places to conduct high-altitude and scientific experiments
    - Experiments can be conducted up to 5,000m altitude
- Agriculture Land Management
  - Management of agriculture land parcels
    - Land-pulling and land management
  - Assist in Farming

Our Activities to Promote GNSS Technology

UN-Nepal Workshop on GNSS

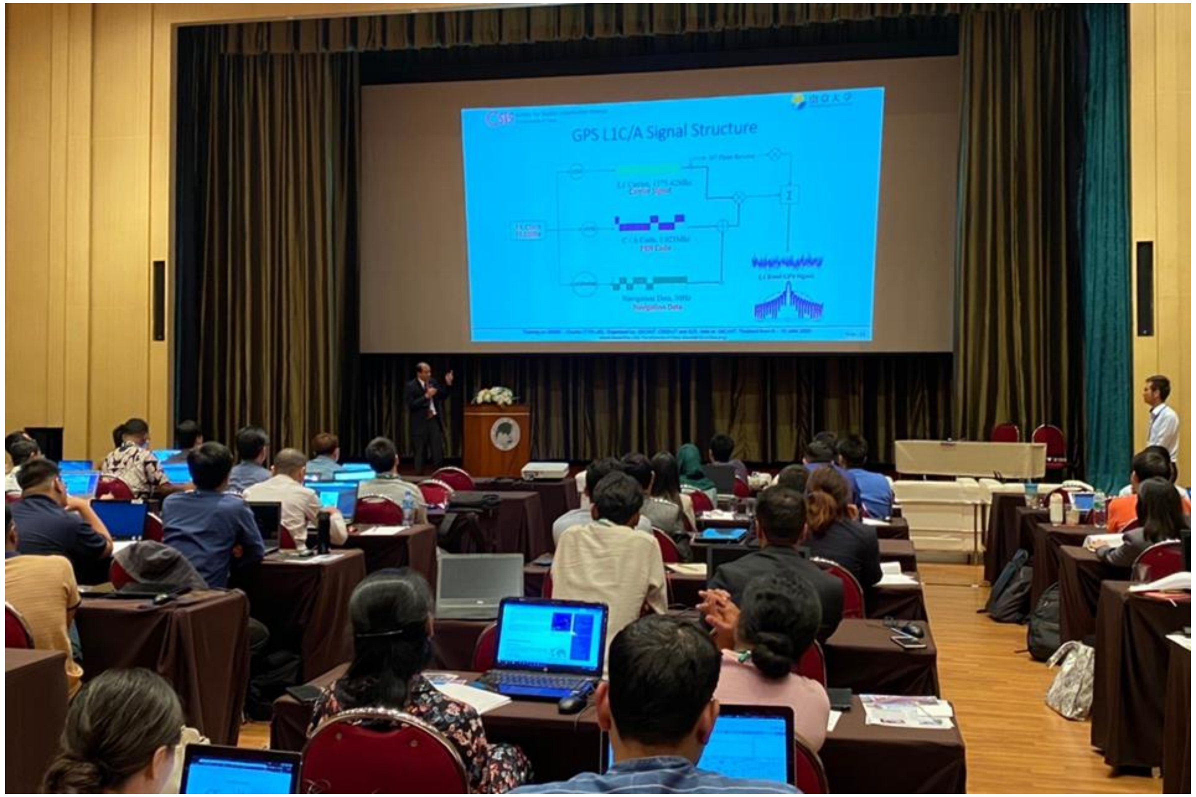
12 – 16 DEC 2016

- Organized by Survey Dept. of Nepal and UNOOSA/ICG
- **<u>Total 154 participants from 32 different countries</u>**
- **<u>66 International participants from 31 countries</u>**
- 25 International participants were fully funded by ICG
- Full Five days workshop including ICG's IDM WG Meetings

Global Navigation Satellite System (GNSS) Training, Course T-151

6 – 10 JAN 2020, AIT Conference Center, AIT, Thailand

GNSS Training Lectures : 2020



GNSS Field Survey and Data Processing, 2019

Contact and Additional Information

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  - Main Page : https://home.csis.u-tokyo.ac.jp/~dinesh/
  - Webinar Page : https://home.csis.u-tokyo.ac.jp/~dinesh/WEBINAR.htm
  - Training Data : https://home.csis.u-tokyo.ac.jp/~dinesh/GNSS_Train.htm
  - Low-Cost Receiver : https://home.csis.u-tokyo.ac.jp/~dinesh/LCHAR.htm
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- GPS for Earthquake Measurement
  - Displacement :: 2011 Tohoku-oki Earthquake (caltech.edu)
  - https://youtu.be/1HONU8jlBuU