January 29, 2025

INTRODUCTION OF MALIB OPEN-SOURCE MADOCA-PPP SOFTWARE

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Satellite Navigation Unit
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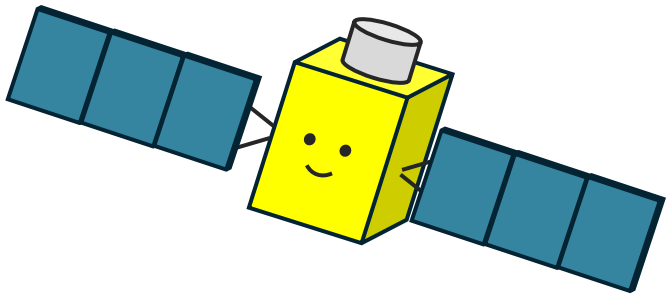
Today’s Agenda



Agenda

1. Introduction | What is MALIB and MADOCA-PPP
2. PPP software | RTKLIB and MALIB
3. How to use | Quick setup of MALIB
4. Example | Use case of MALIB

Output

- ✓ Understanding MADOCA PPP fundamentals
- ✓ Installing and operating MALIB software & Executing PPP positioning
- ✓ Exploring real-world applications

1. Transportation

- Intelligent Transport Systems
- Public Transport Monitoring
- Aviation / Drone
- Marine
- Toll Charge

2. Timing Application

- Internet
- Financial Institutes
- Power Grids

4. Precise Agriculture

- Smart track
- Drone

3. Logistics

- Management and Monitoring
- Tracking

5. Emergency

- Location beacon
- Tsunami / Earthquake / Landslide

GNSS Positioning methods

Single

1 receiver
Code range
Precise : ~10 m

Differential GPS

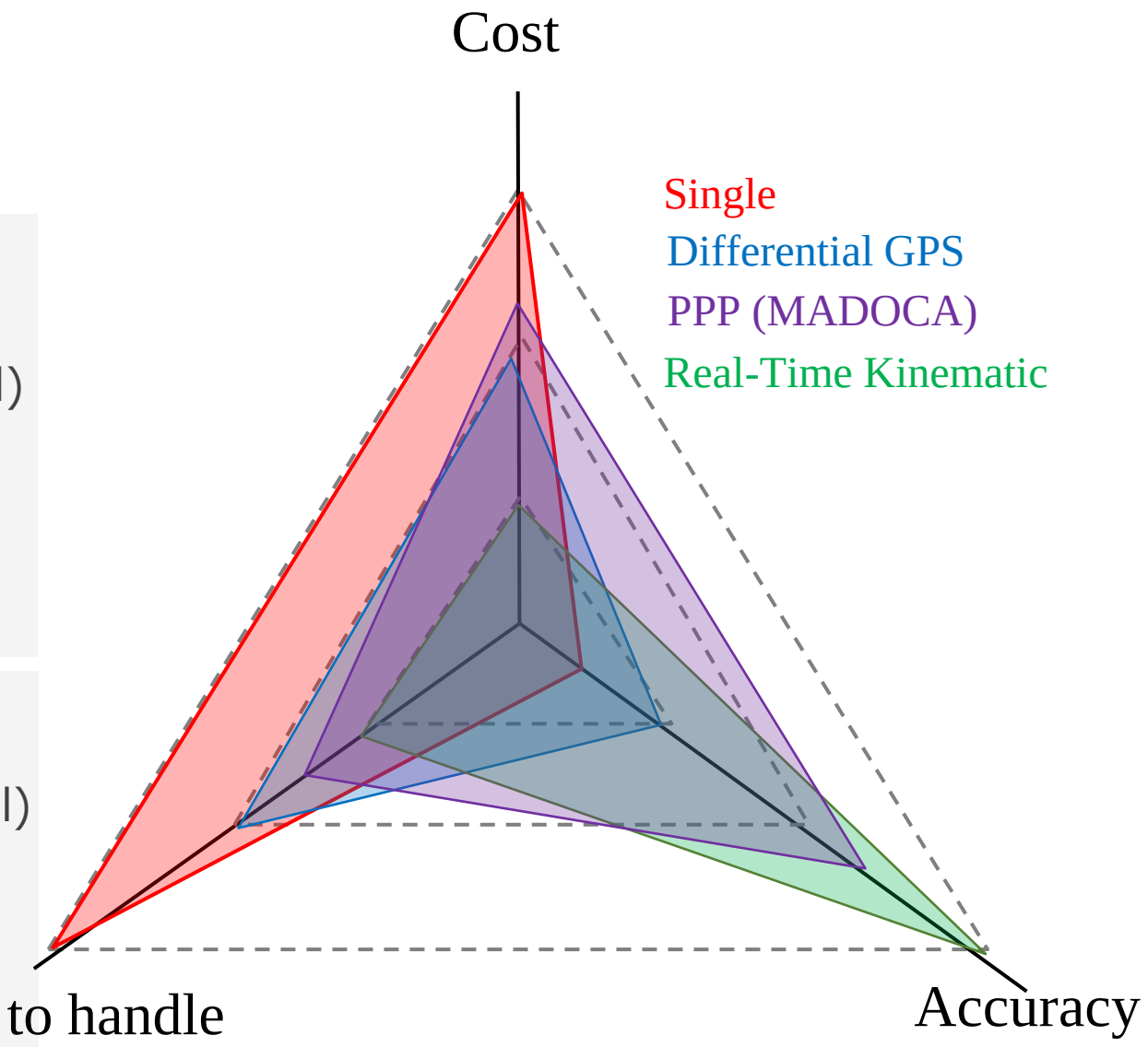
2 receiver (differential)
Code range
Precise : 2-3 m

PPP (MADOCA)

1 receiver
Phase range
Precise :
30 cm~a few cm

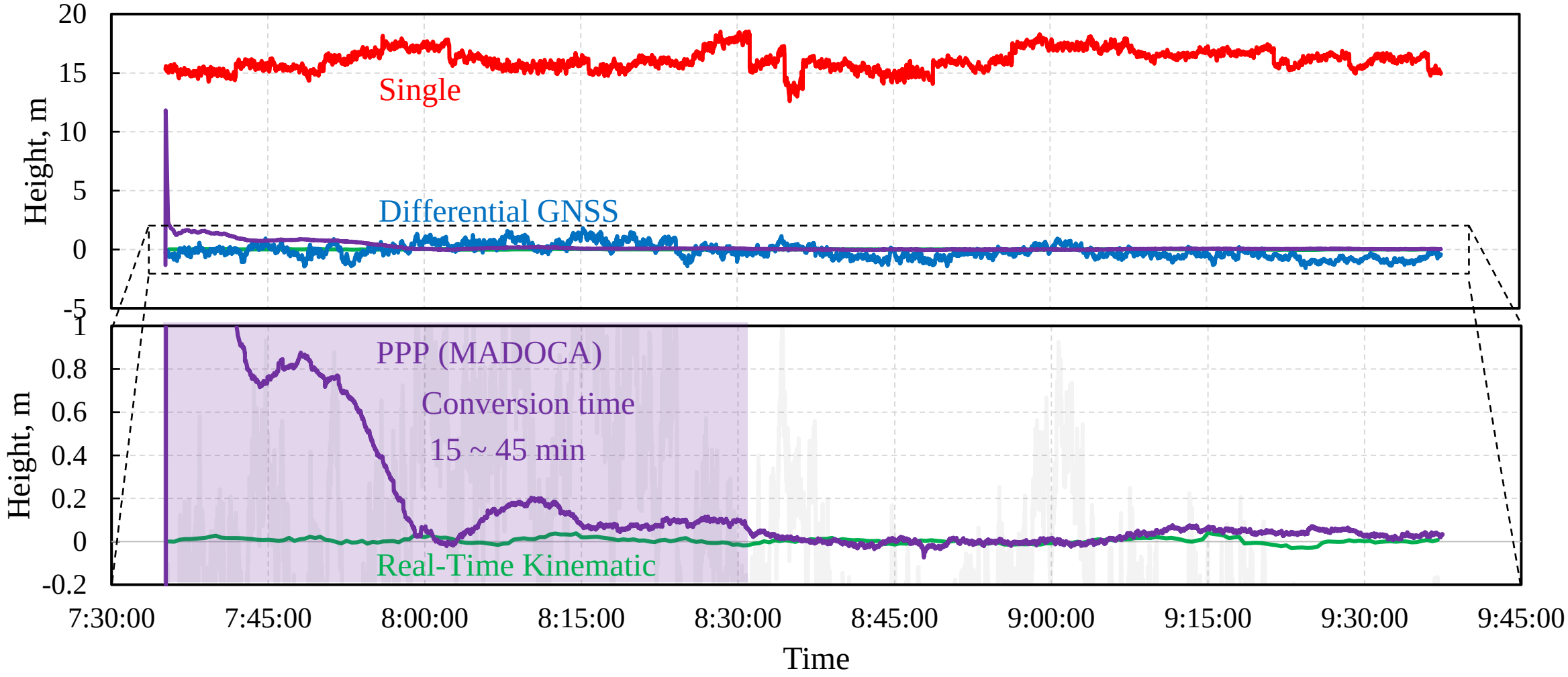
Real-Time Kinematic

2 receiver (differential)
Phase range
Precise : a few cm



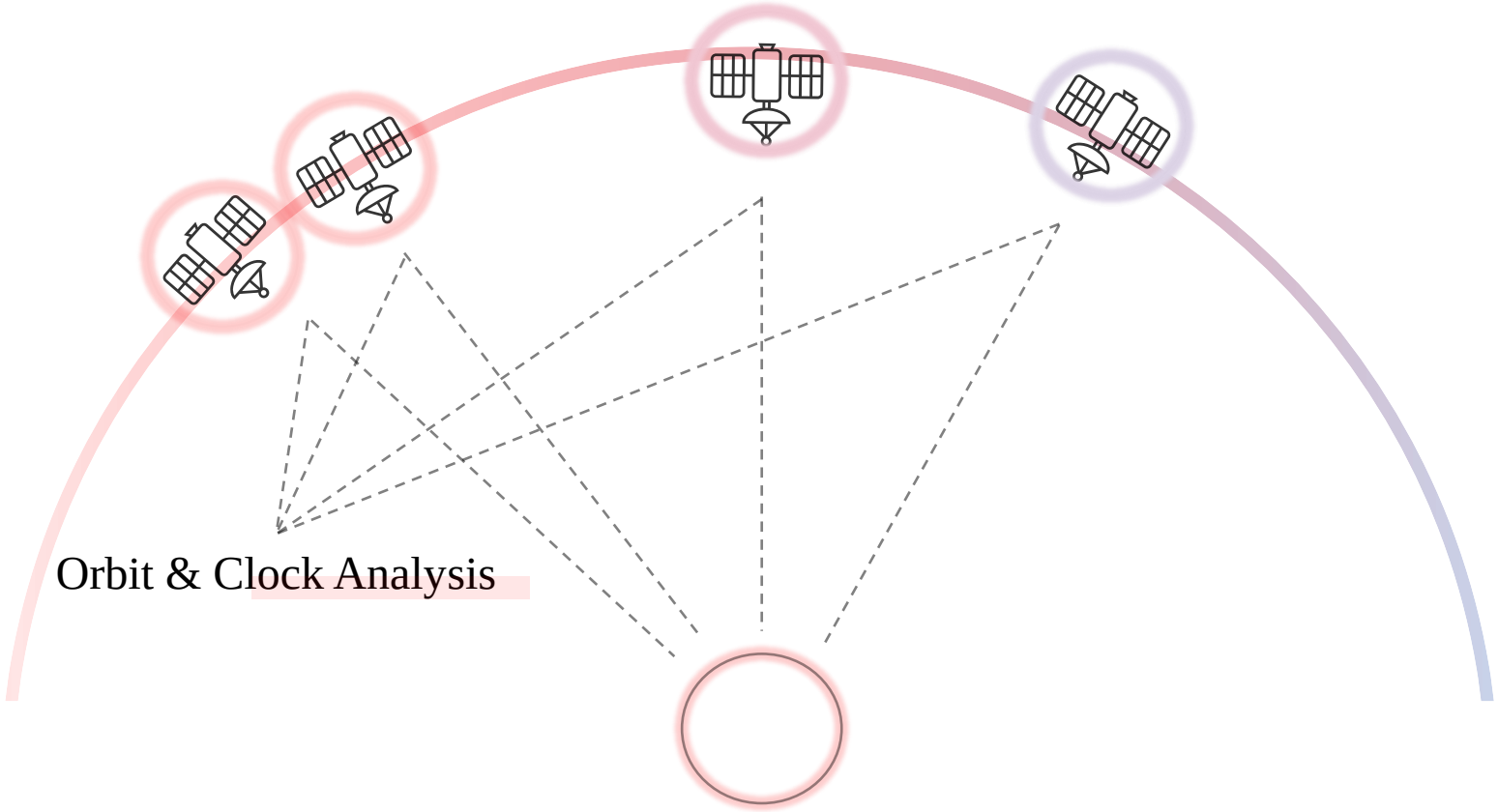
Comparison of GNSS Positioning

Single / Differential GNSS / PPP / RTK



What is MADOCA

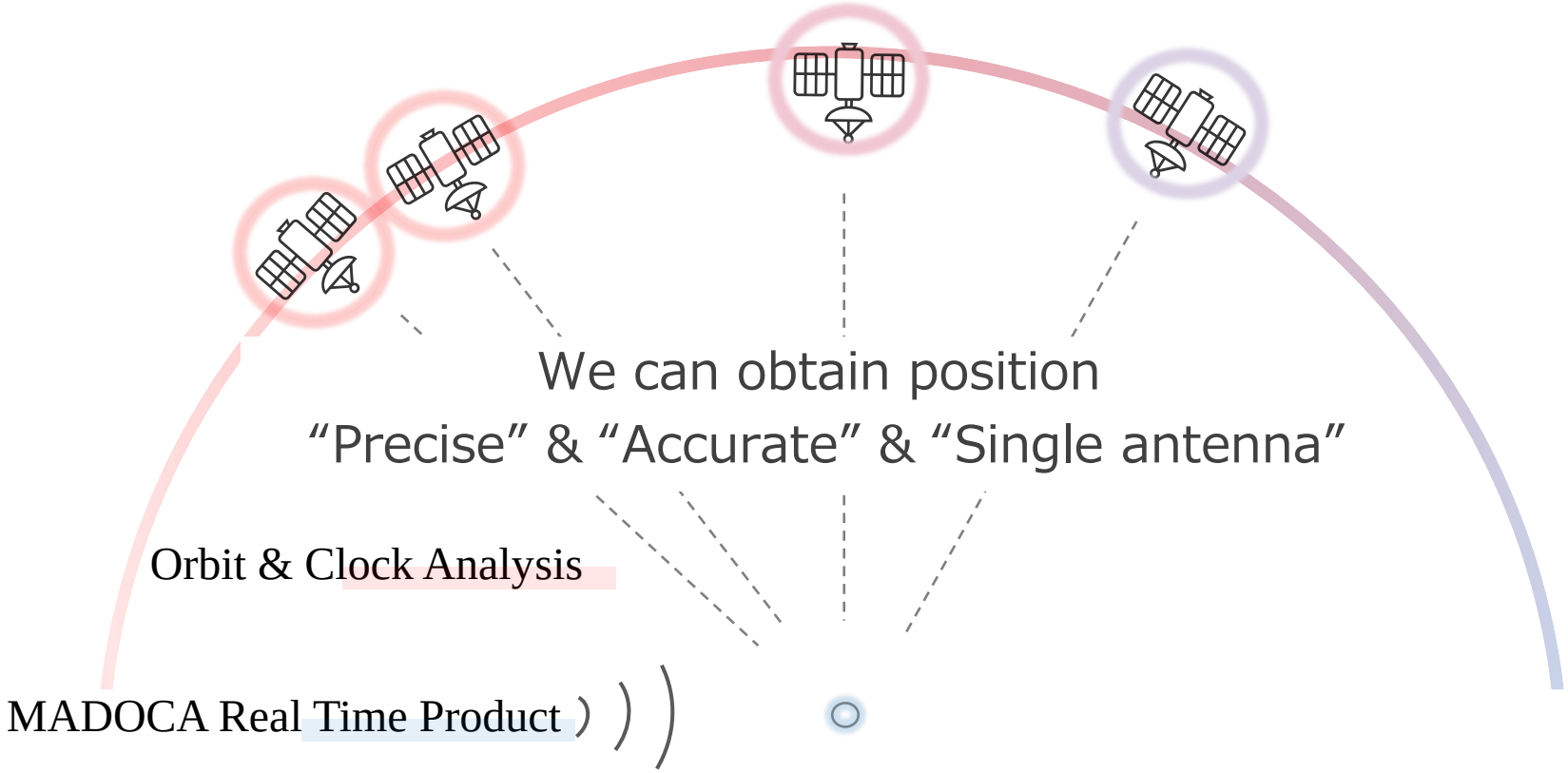
MADOCA : **M**ulti-GNSS **Ad**vanced **O**rbit and **C**lock **A**ugmentation



What is MADOCA-PPP

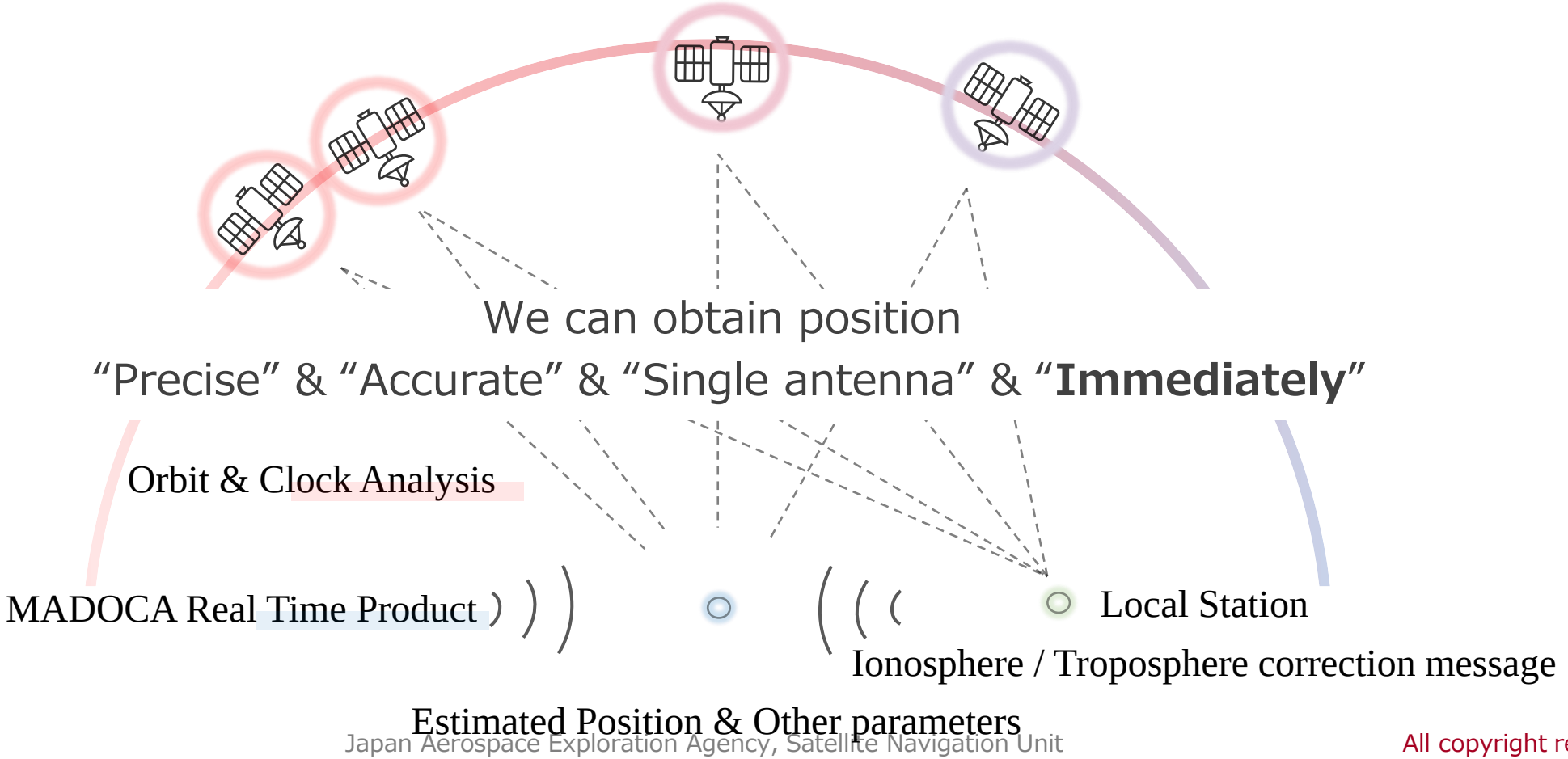
MADOCA : **M**ulti-GNSS **A**dvanced **D**emonstration tool for **O**rbit and **C**lock **A**nalysis

PPP : **P**recise **P**oint **P**positioning



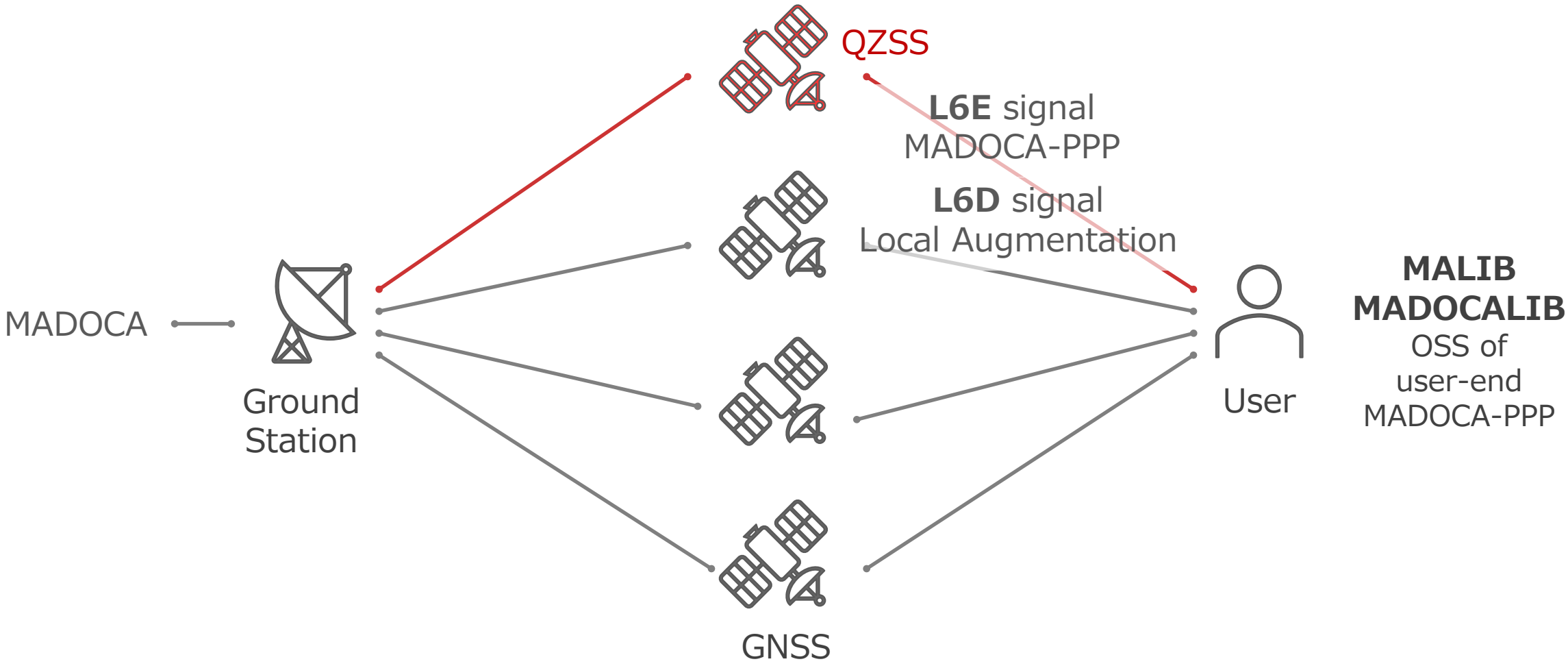
MADOCA-PPP local augmentation

Initial convergence time and **TTFF** (Time To First Fix) can be saved estimating ionosphere/troposphere error by using Local station



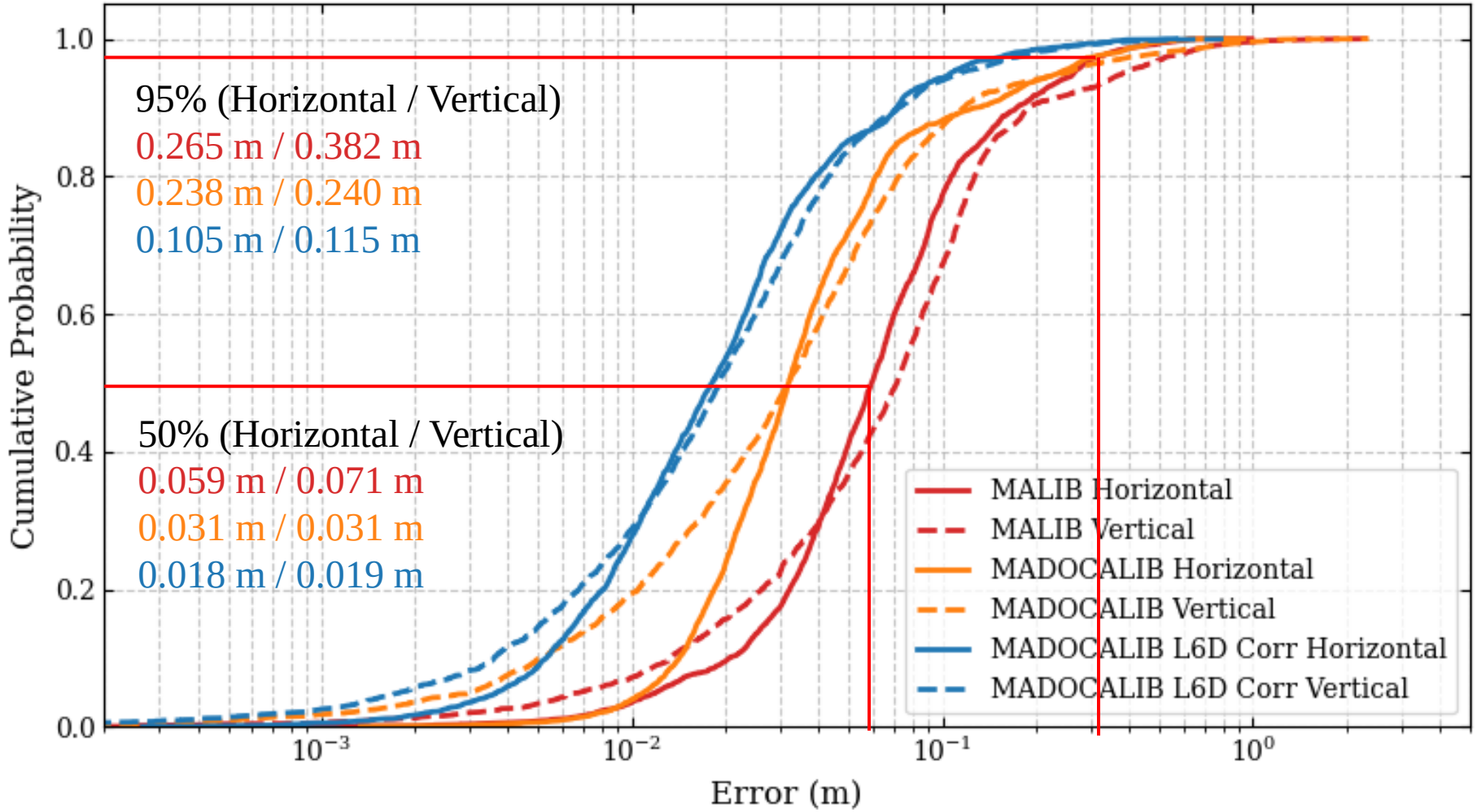
Overview of MADOCA & MALIB

MALIB : User-end MADOCA-PPP software



Error Distribution of MALIB / MADOCALIB

CAO MADOCALIB Sample data (Tsukuba-2, 24 hour (divided 1 hour & execute), Open-sky)



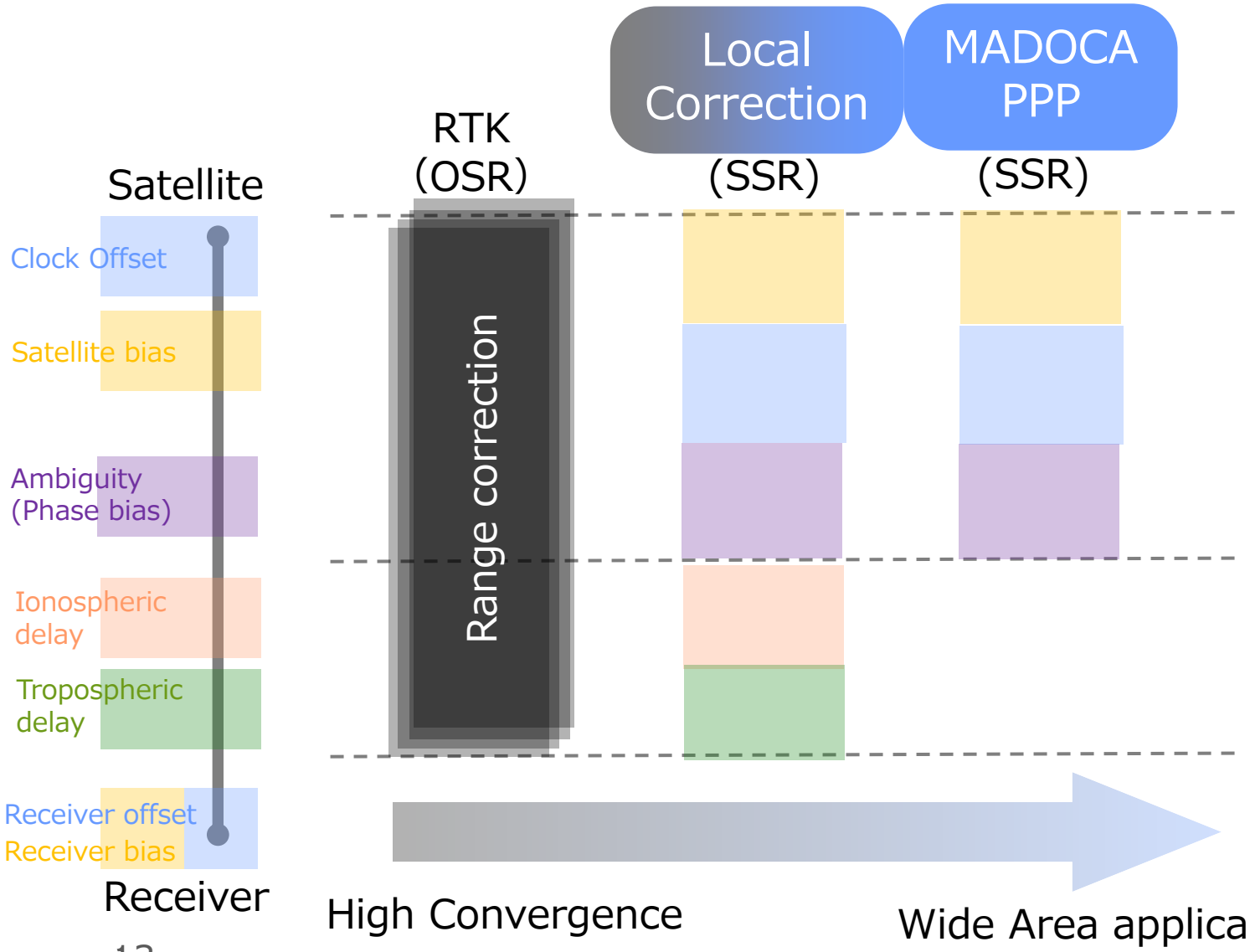
QZSS Signals

Service name		Signal Name	Center Frequency [MHz]	QZSS							
				QZS -1	QZS -2	QZS -3	QZS -4	QZS -1R	QZS -5	QZS -6	QZS -7
				QZO		GEO	QZO			GEO	準静止軌道
Positioning service	Positioning Service	L1C/A	1575.42	○	○	○	○	*1	*2	*2	*2
		L1C/B		–	–	–	–	*1	○	○	○
		L1C		○	○	○	○	○	○	○	○
		L2C	1227.6	○	○	○	○	○	–	–	–
		L5	1176.45	○	○	○	○	○	○	○	○
Augmentation service	Sub-meter Level Augmentation Service (SLAS)	L1S	1575.42	○	○	○	○	○	–	–	–
	Centimeter Level Augmentation Service (CLAS)	L6D	1278.75	○	○	○	○	○	–	–	–
	High-Precision Positioning Service (MADOCA-PPP)	L6D		–	–	–	–	–	○	○	○
		L6E		–	○	○	○	○	○	○	○
Other services	Disaster & Crisis Management Report (DC-Report)	L1S	1575.42	○	○	○	○	○	–	–	–
	SBAS Transmission	L1Sb		–	–	○	–	–	–	○	○
	Technology Verification	L5S	1176.45	–	○	○	○	○	–	○	○
	Health Monitoring (Q-ANPI)	S-Band	2000	–	–	○	–	–	–	–	○

Mitigation strategies of PPP error sources

Effect	Magnitude	Domain	Mitigation Strategy	Residual error
Ionosphere	10 m	Range	IFLC / STEC	mm
Troposphere	Few m	Range	Modeling	dm mm
Relativity	10 m	Range	Modeling	mm
Satellite antenna PCO/PCV	m cm	Position; range	Modeling	mm
Solid earth tide	20 cm	Position	Modeling	mm
Phase windup	10 cm	Range	Modeling	mm
Ocean loading	5 cm	Position	Modeling	mm
Satellite orbits/clocks	Few cm	Position; range	Modeling	mm
Pseudorange multipath and noise	1-3 m	Range	Filtering	dm mm
Receiver antenna PCO/PCV	cm mm	Position; range	Modeling	mm

Carrier Phase Positioning | Correction

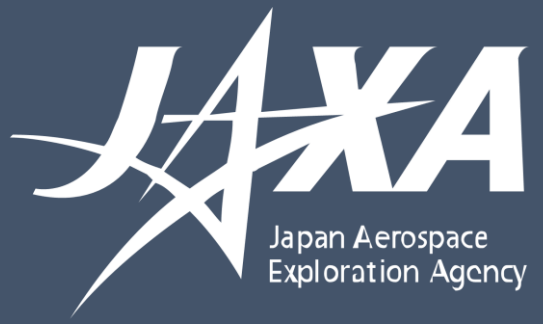


OSR : Observation Space Representation

Use observation data directly as correction values

SSR : State Space Representation

Separate and use physical quantities of error sources contained in observation data



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PPP SOFTWARE : RTKLIB & MALIB

PPP Correction service

System	Service	Satellite	Status	Data Rate	Format
QZSS CLAS	Nationwide PPP-RTK	IGSO/GEO	Operational (2018-)	2,000 bps	Compact SSR
QZSS MADOCA	**Regional PPP**	**IGSO/GEO**	**Operational (2023-)**	**2,000 bps**	**Compact SSR**
GALILEO HAS	Global PPP	MEO	Operational (2023-)	500 bps	Base on Compact SSR
BeiDou PPP	Regional PPP	GEO	Operational (2020-)	500 bps	SSR (PPP-B2bl ICD)
SouthPAN PVS	Regional PPP	GEO	Development (2023-)	250 bps	Under definition
GLONASS PPP	Regional PPP	GEO	Concept (2030-)	4,000 bps	RTCM SSR

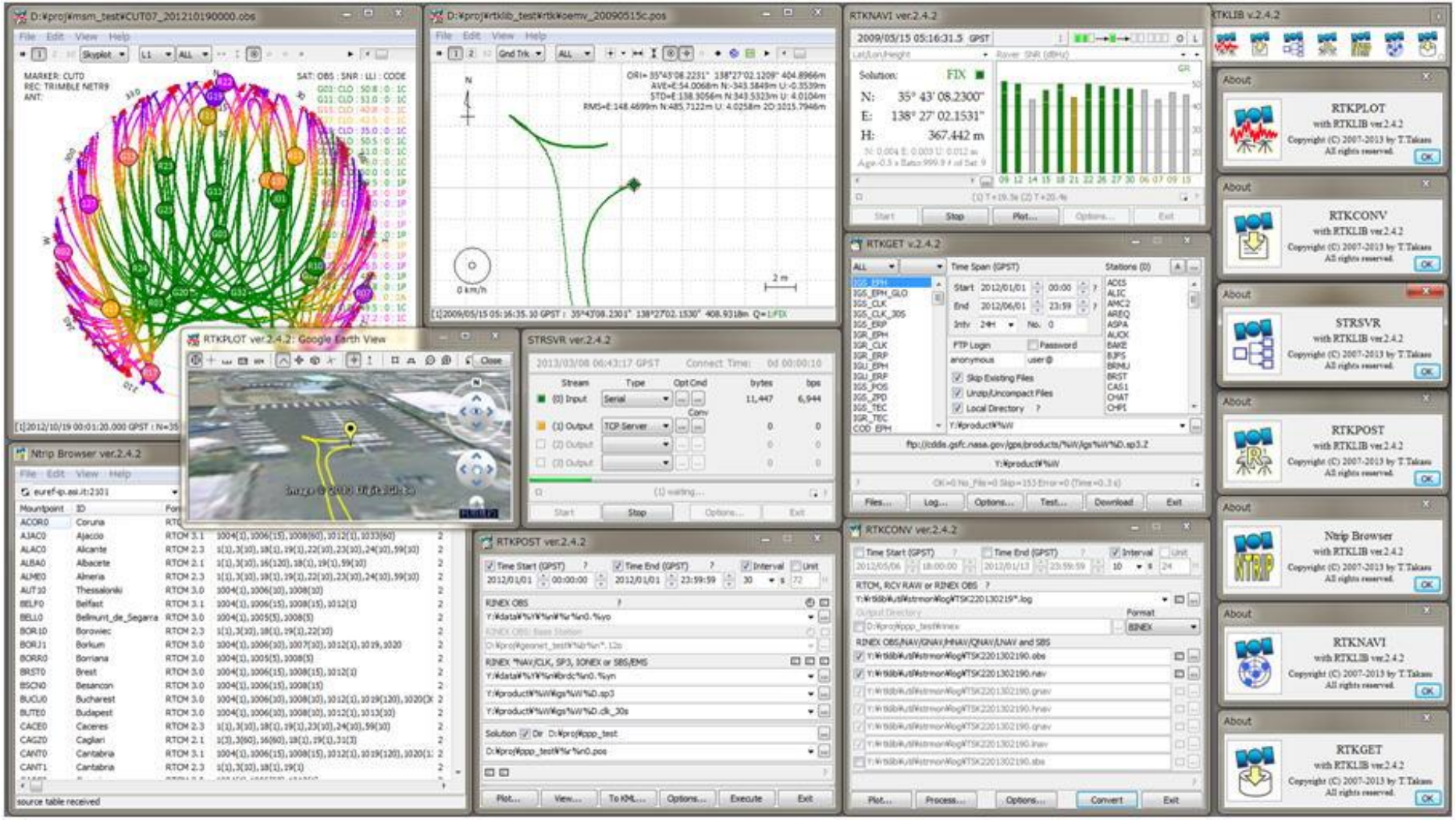
PPP/PPP-RTK open formats: Overview, comparison, and proposal for an interoperable message, Rui Hirokawa, et. al. First published: 15 December 2021 https://doi.org/10.1002/navi.452

PPP | Open-Source Software

	Developer	Stars	Fork	Watch	License	Last update
RTKLIB	Tomoji Takasu	2.5k	297	1.6k	BSD-2.0	4 years ago
GSILIB	GSI	-	-	-	BSD-2.0 GPL v3	2022/08/30
MALIB	JAXA	25	0	1	BSD-2.0	2024/09/30
MADOCALIB	CAO	28	2	11	BSD-2.0	2024/08/23
CLASLIB	CAO	15	2	11	BSD-2.0	2024/06/27
PRIDE	Wuhan University	257	35	101	GPL-3.0	2024/10/04
Ginan	Geoscience Australia	226	108	29	Apache v2	2024/10/12
GipsyX	NASA JPL	-	-	-	-	2024/09/04
PPP-WIZARD	CNES	-	-	-	-	2024/07/12
CSRS-PPP	NRCan	-	-	-	-	2022/11/27
PPPLib	Chao Chen	29	2	66	-	4 years ago

Contributor : 8

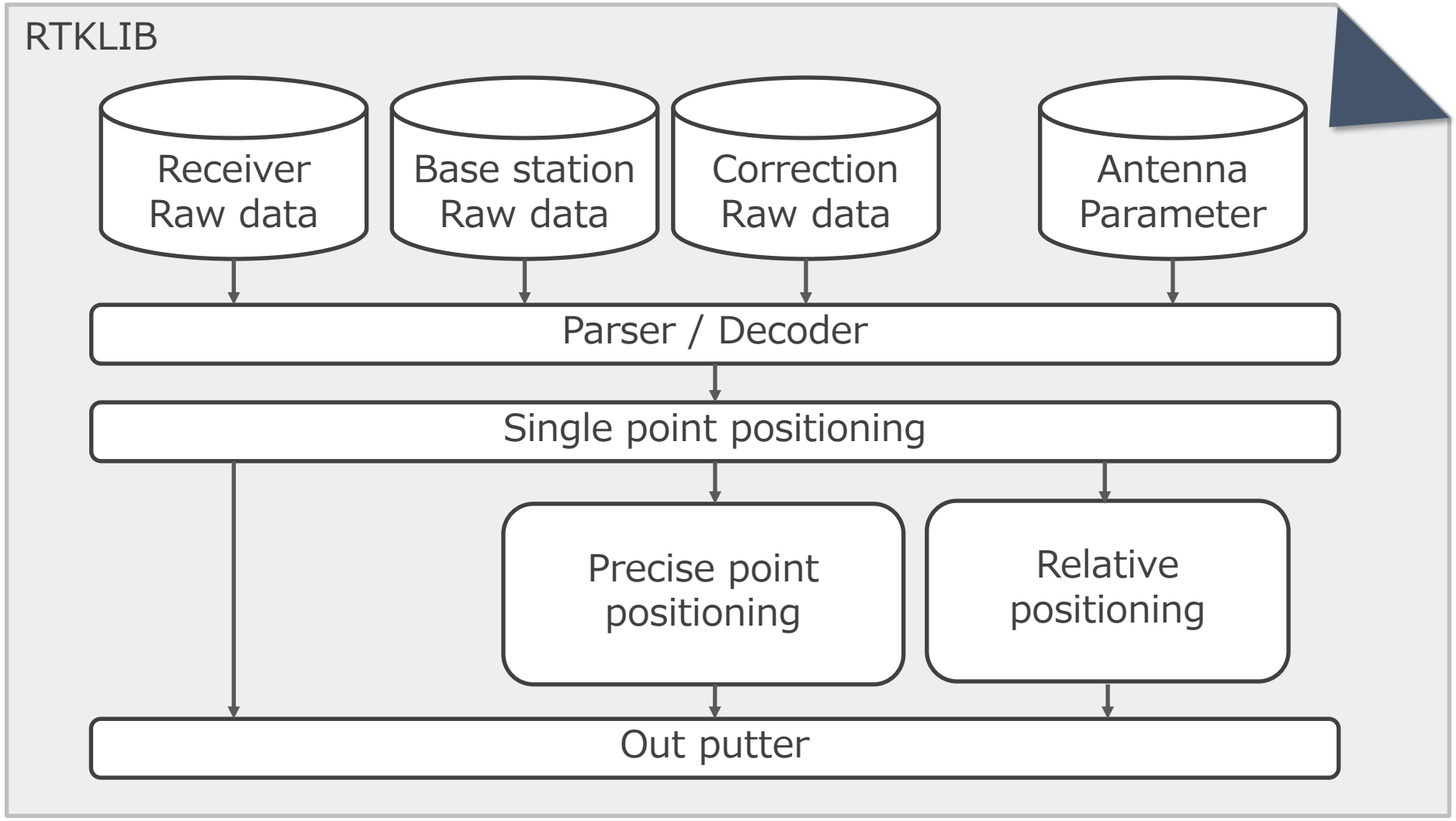
What is RTKLIB ?



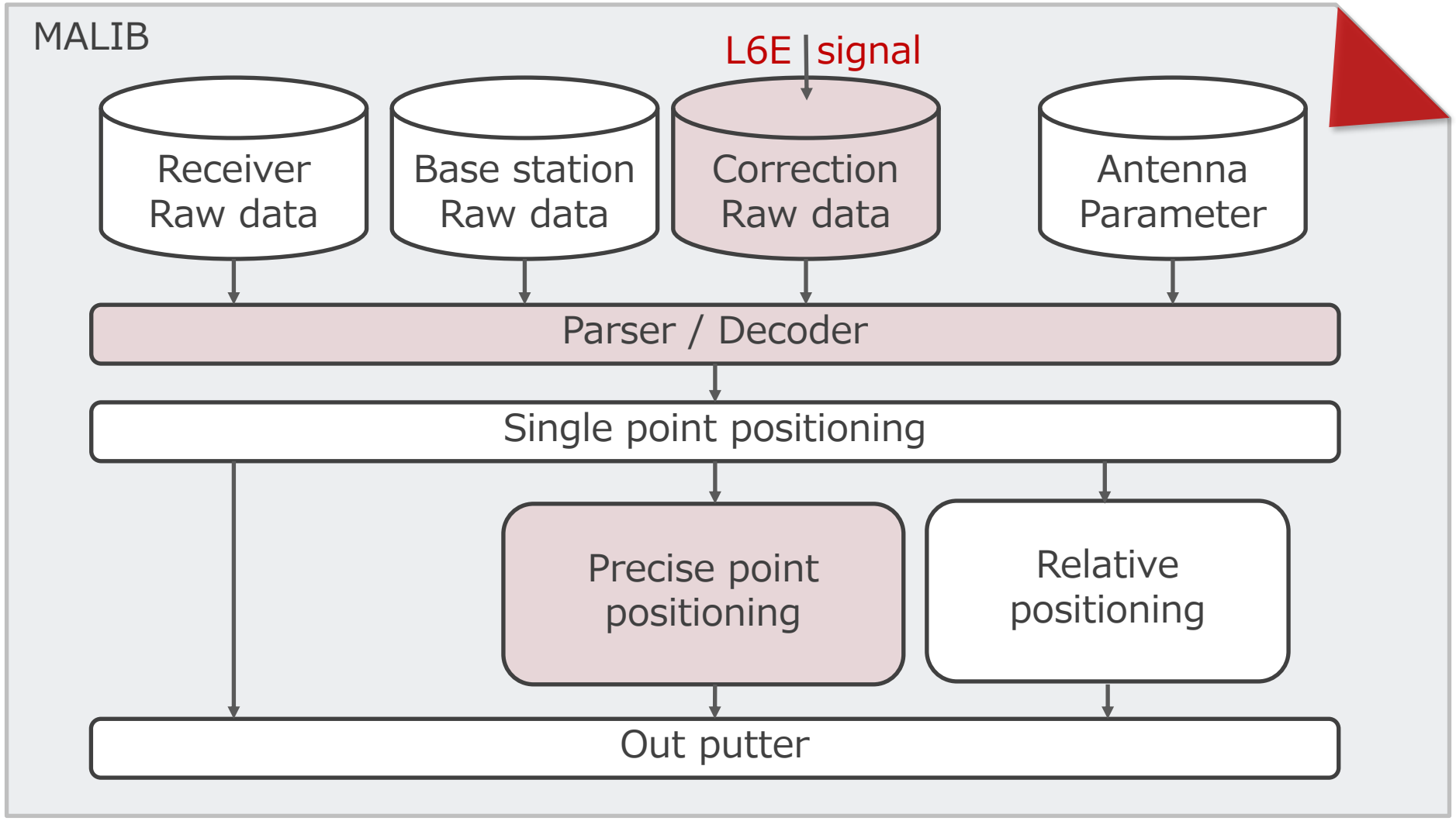
MALIB Open-Source Software released !!!

https://www.satnavi.jaxa.jp/ja/news/2024/10/04/9950/index.html
https://github.com/JAXA-SNU/MALIB

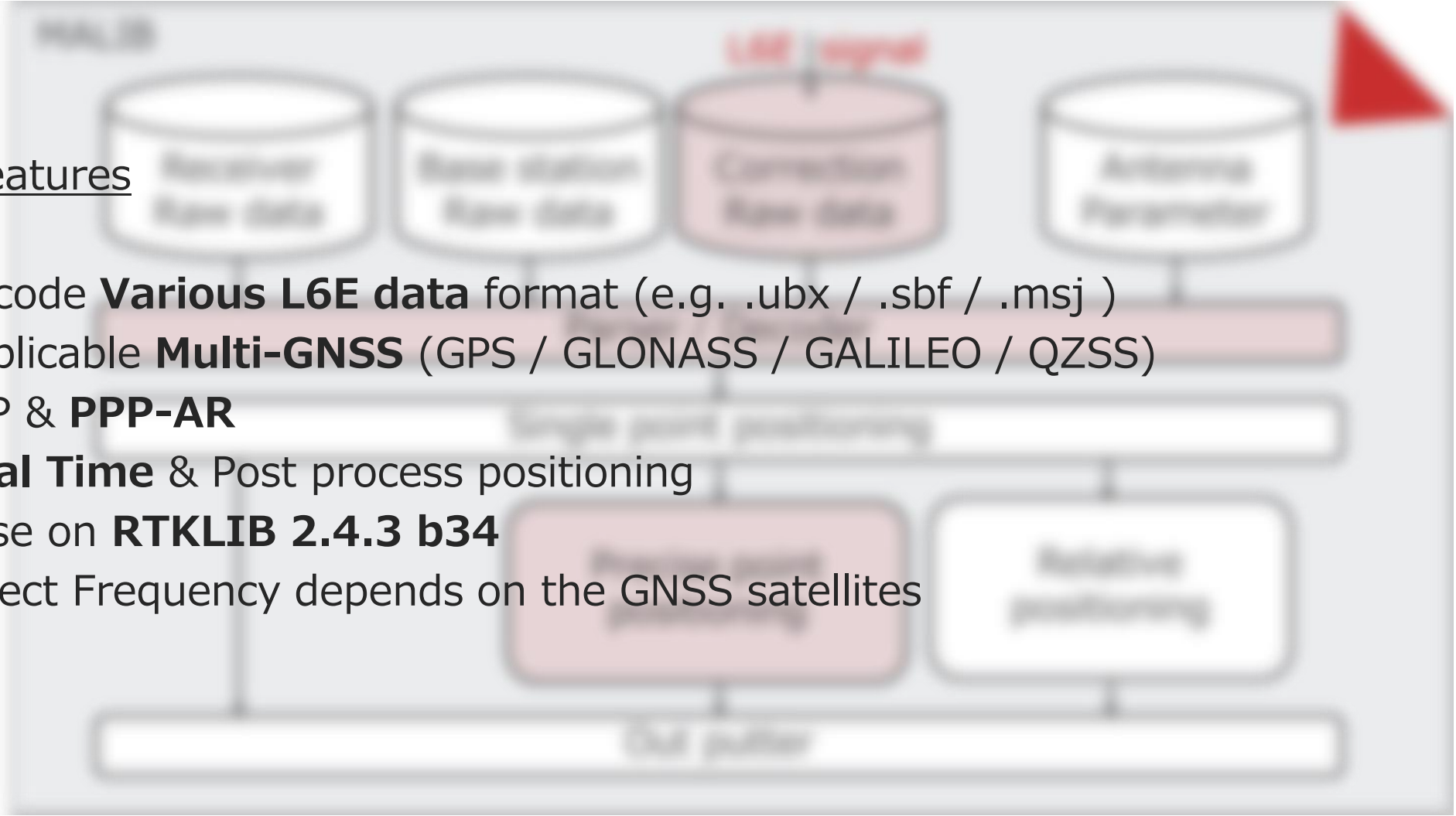
RTKLIB | GNSS Open-Source Software



MALIB | MADOCA-PPP Open-Source Software

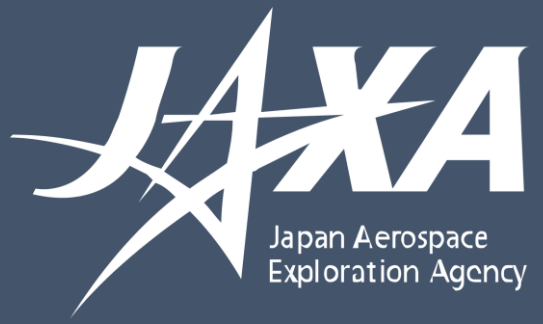


MALIB | MADOCA-PPP Open-Source Software



Key features

- Decode **Various L6E data** format (e.g. .ubx / .sbf / .msj)
- Applicable **Multi-GNSS** (GPS / GLONASS / GALILEO / QZSS)
- PPP & **PPP-AR**
- **Real Time** & Post process positioning
- Base on **RTKLIB 2.4.3 b34**
- Select Frequency depends on the GNSS satellites



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HOW TO INSTALL MALIB

How to install MALIB on your system

https://github.com/JAXA-SNU/MALIB

Functions of RTKLIB

Linux

- rtkrcv : Real-time positioning (console)
- rnx2rtkp : Post process (console)
- str2str : Stream server (console)
- convbin : Binary to RINEX converter (console)
- pos2kml : Google Earth KML converter (console)

Windows

- rtkconv : Binary to RINEX converter (GUI)
- srctblbrows : Ntrip source table browser (GUI)
- rtknavi : Real-time positioning (GUI)
- rtkplot : Plot position & observation data (GUI)
- rtkpost : Post process (GUI)
- strsvr : Stream server (GUI)

Functions of MALIB

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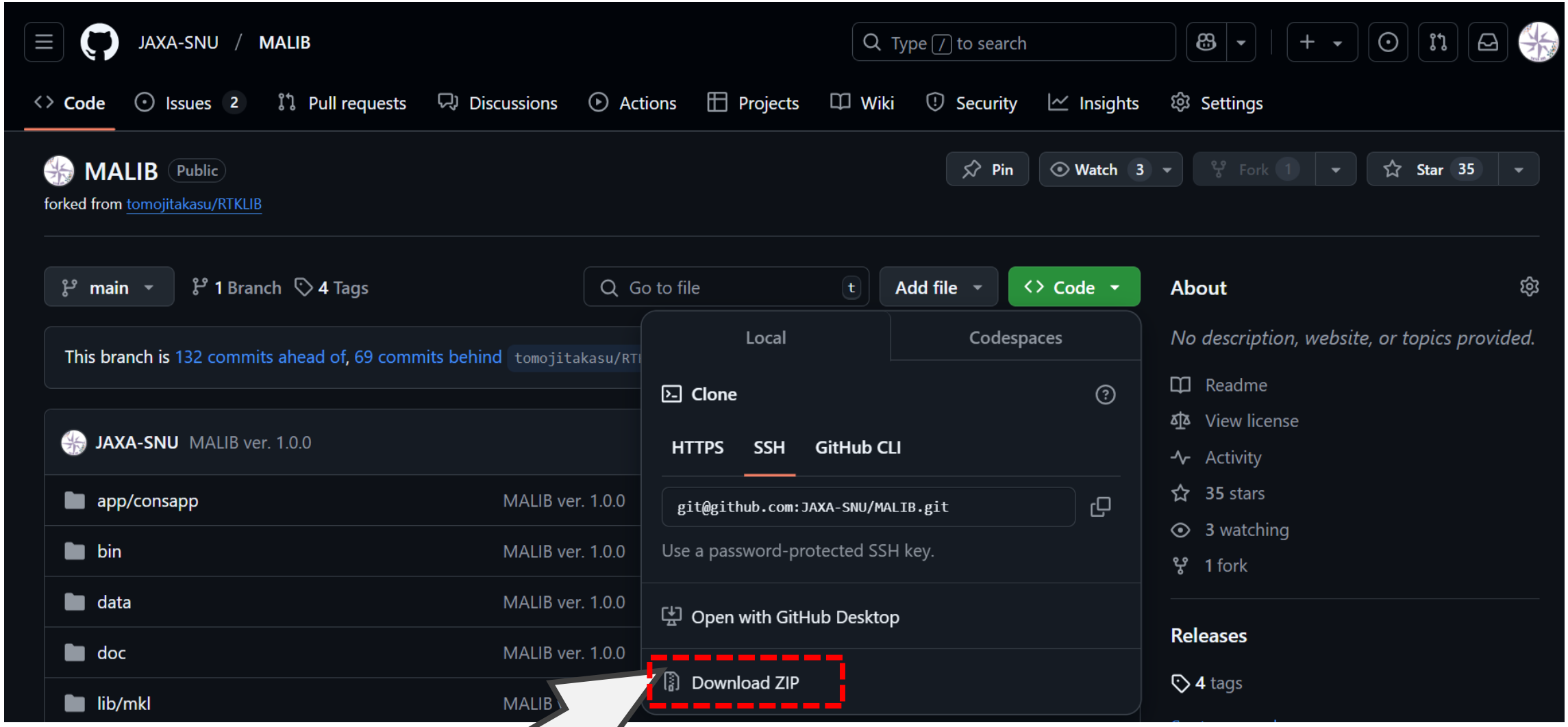


Click & Download or git clone git@github.com:JAXA-SNU/MALIB.git

Folder structure of MALIB

JAXA-SNU MALIB ver. 1.0.0 — 159e150 · 4 months ago — 132 Commits

app/consapp	MALIB ver. 1.0.0	4 months ago
bin	MALIB ver. 1.0.0	4 months ago
data	MALIB ver. 1.0.0	4 months ago
doc	MALIB ver. 1.0.0	4 months ago
lib/mkl	MALIB ver. 1.0.0	4 months ago
src	MALIB ver. 1.0.0	4 months ago
test	RTKLIB 2.4.3 b34	5 years ago
util	RTKLIB 2.4.3 b34	5 years ago
.gitattributes	RTKLIB 2.4.2	12 years ago
.gitignore	RTKLIB 2.4.3 b34	5 years ago
LICENSE.txt	MALIB ver. 1.0.0	4 months ago
readme.md	MALIB ver. 1.0.0	4 months ago

Application

Binary file of executable

Data folder

Document folder

Library of MKL

Source code of MALIB

Test code

Utility file

rtkrcv | real-time processing application

- step. 0 | clone GitHub link or download zip file from GitHub
  git clone https://github.com/JAXA-SNU/MALIB.git
  cd MALIB

- step. 1 | Unzip test data
  tar -zxvf ./data/MALIB_OSS_data.tar.gz -C ./

- step. 2 | Compile rtkrcv
  cd ./app/consapp/rtkrcv/gcc/
  make clean
  make
  make install
  cd ./../../../../

rtkrcv | real-time processing application

- step. 3 | Execute rtkrcv (replay processing)

  ./bin/rtkrcv –o ./bin/rtkrcv.conf

Tips

usage: rtkrcv [-s][-p port][-d dev][-o file][-w pwd][-r level][-t level][-sta sta]

options

-s	start RTK server on program startup
-p port	port number for telnet console
-m port	port number for monitor stream
-d dev	terminal device for console
-o file	processing options file
-w pwd	login password for remote console ("": no password)
-r level	output solution status file (0:off,1:states,2:residuals)
-t level	debug trace level (0:off,1-5:on)
-sta sta	station name for receiver dcb
-v|-ver	print version
-rst	ds ts start day/time (ds=y/m/d ts=h:m:s) [raw/rtcm data start time]

rtkrcv | real-time processing application

- step. 4 | Execute rtkrcv (replay processing)
  ./bin/rtkrcv –o ./bin/rtkrcv.conf

Tips

```
** rtkrcv ver.1.0.0  console (h:help) **
rtkrcv> start
rtk server start
rtkrcv> sol
2024/08/22 10:59:49.0 (PPP   ) N:36.06873342 E:140.12835085 H: 114.218
2024/08/22 10:59:50.0 (PPP   ) N:36.06873356 E:140.12835072 H: 114.239
2024/08/22 10:59:51.0 (PPP   ) N:36.06873409 E:140.12834980 H: 114.198

rtkrcv> stat
Parameter                : Value
malib version            : 1.0.0
rtk server thread        : -544123328
rtk server state         : run
...
```

rtkrcv | real-time processing configuration file

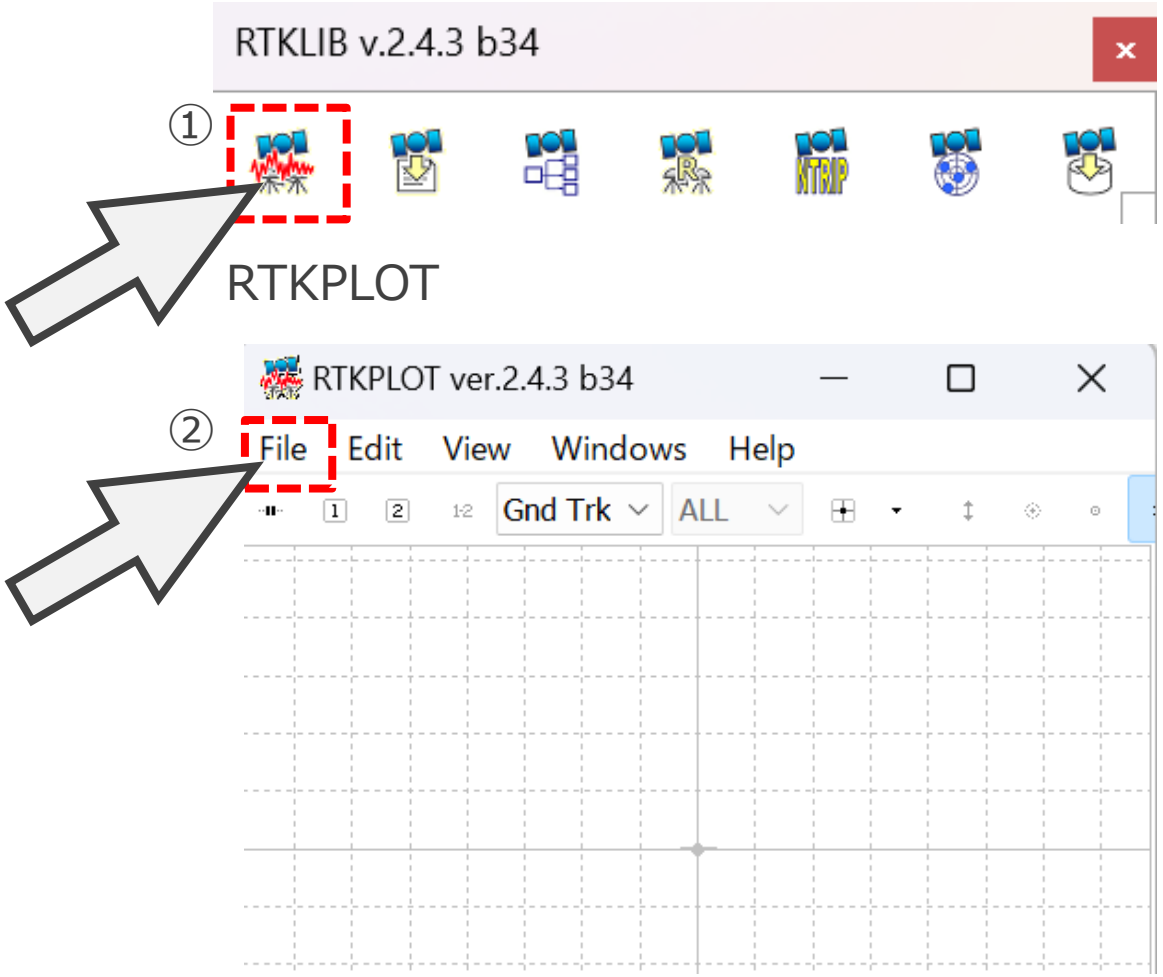
- # Input stream type (0:off,1:serial,2:file,3:tcpsvr,4:tcpcli,7:ntripcli,8:ftp,9:http)
- inpstr1-type =ntripcli
- inpstr2-type =off
- inpstr3-type =ntripcli

- # Input stream path
- inpstr1-path =[user[:passwd]]@addr:port/mntpnt
- inpstr2-path =
- inpstr3-path =[user[:passwd]]@addr:port/mntpnt

- # Input stream format (0:rtcm2,1:rtcm3,2:oem4,3:oem3,4:ubx,5:ss2,6:hemis,7:skytraq,8:sp3)
- inpstr1-format =rtcm3
- inpstr2-format =
- inpstr3-format =rtcm3

rtkrcv | real-time processing application

- step. 4 | plot data (e.g. RTKPLOT in RTKLIB)



rnx2rtkp | post processing application

- step. 0 | clone GitHub link or download zip file from GitHub
  git clone https://github.com/JAXA-SNU/MALIB.git
  cd MALIB

- step. 1 | Unzip test data
  tar -zxvf ./data/MALIB_OSS_data.tar.gz -C ./

- step. 2 | Compile rnx2rtkp
  cd ./app/consapp/rnx2rtkp/gcc/
  make clean
  make
  make install
  cd ./../../../../

rnx2rtkp | post processing application

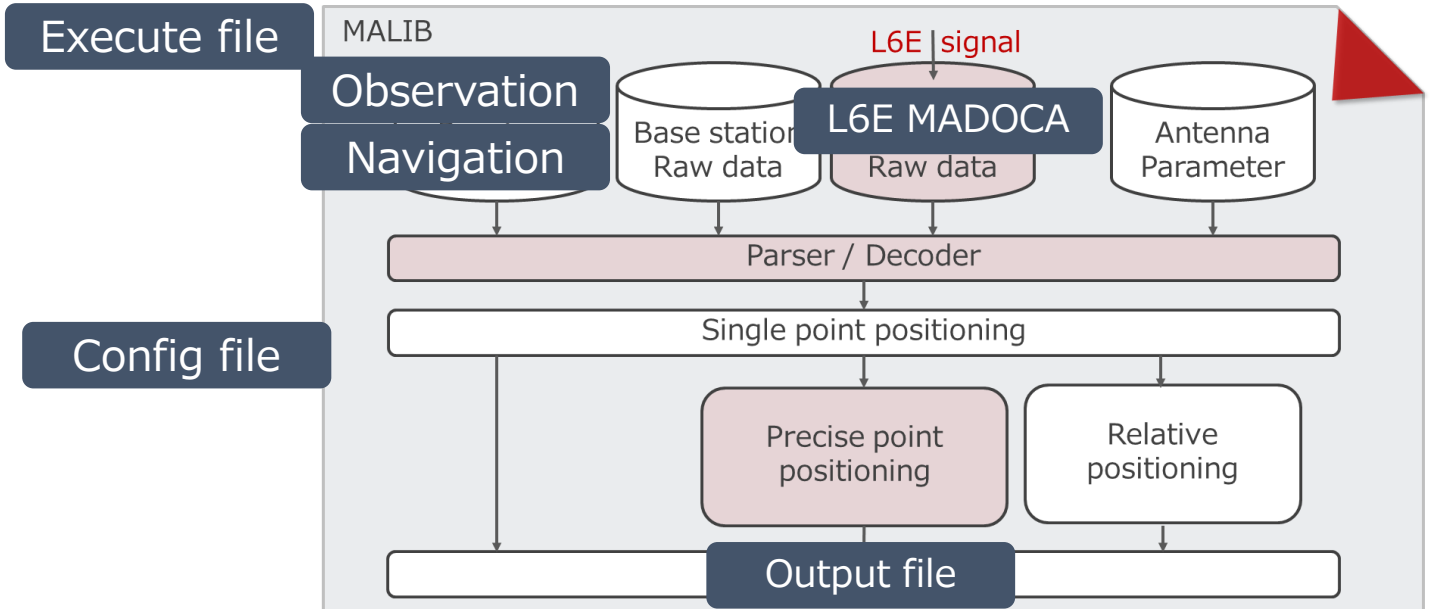
- step. 3 | Execute rnx2rtkp

Execute file	./bin/rnx2rtkp ¥
Config file	> -k ./bin/rnx2rtkp.conf ¥
Observation	> ./data/MALIB_OSS_data_obsnav_240822-1100.obs ¥
Navigation	> ./data/MALIB_OSS_data_obsnav_240822-1100.nav ¥
L6E MADOCA	> ./data/2024235L.209.l6¥
Output file	> -o ./data/out/rnx2rtkp_test.pos

rnx2rtkp | post processing application

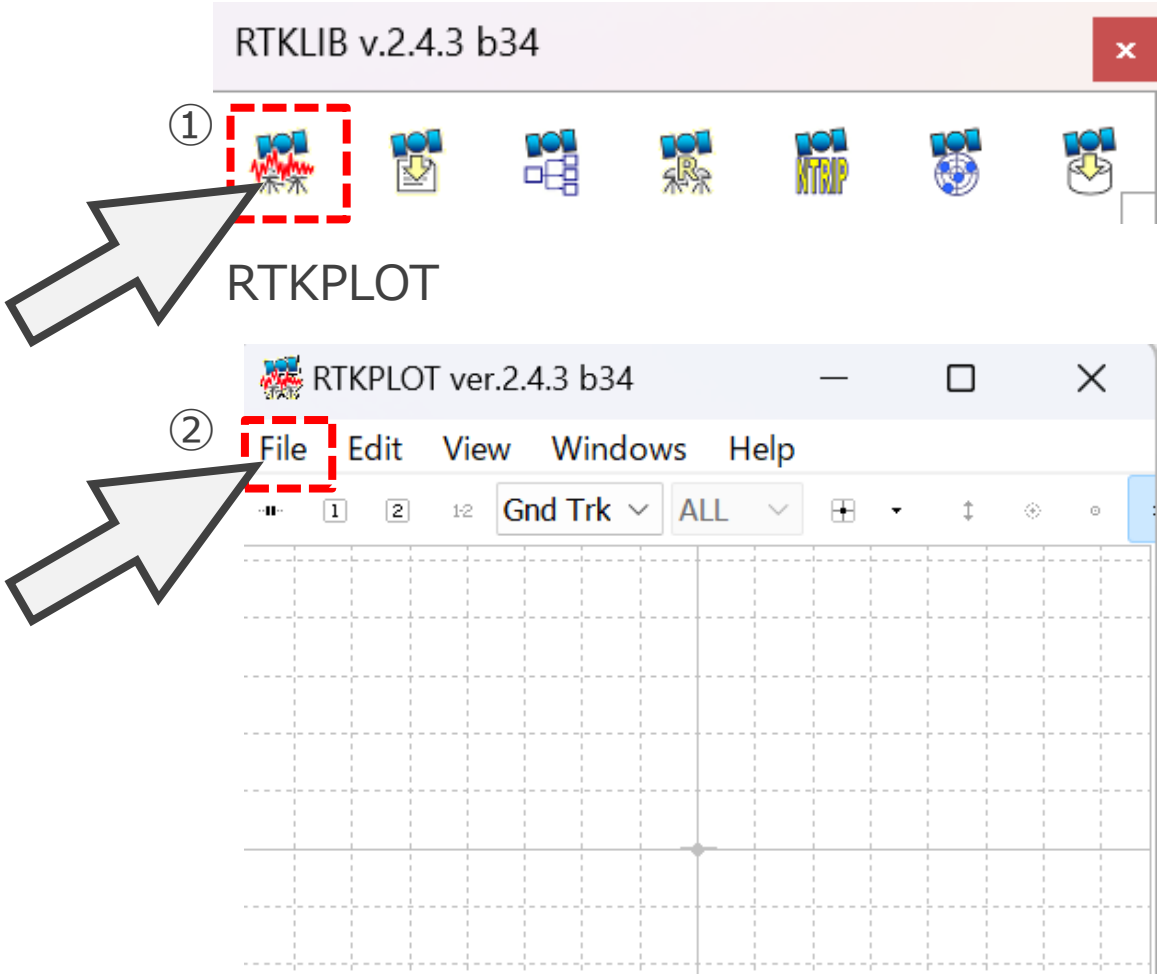
- step. 3 | Execute rnx2rtkp

```
./bin/rnx2rtkp ¥
> -k ./bin/rnx2rtkp.conf ¥
> ./data/MALIB_OSS_data_obsnav_240822-1100.obs ¥
> ./data/MALIB_OSS_data_obsnav_240822-1100.nav ¥
> ./data/2024235L.209.l6¥
> -o ./data/out/rnx2rtkp_test.pos
```



rnx2rtkp | post processing application

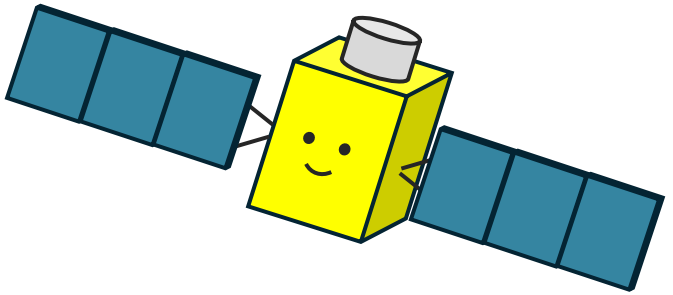
- step. 4 | plot data (e.g. RTKPLOT in RTKLIB)



Summary | MALIB & MADOCA-PPP

MALIB Features
- **Open-source PPP** software based on RTKLIB 2.4.3
- **Multi-GNSS** capability and various L6E signal receiver processing
- **Real-time** & post-processing support
- GitHub: github.com/JAXA-SNU/MALIB

Applications
- Autonomous vehicles (YADOCAR-i)
- Low-cost GNSS receivers (micro computer w/MALIB)
- Integration example with other sensors



Future Development
- Ongoing improvements and updates
- Community contributions welcome
- Let’s expanding application areas together

THANK YOU