High Altitude GNSS Receiver Development in Japan

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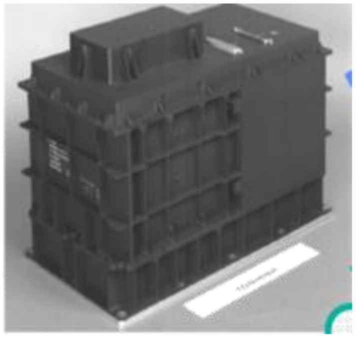
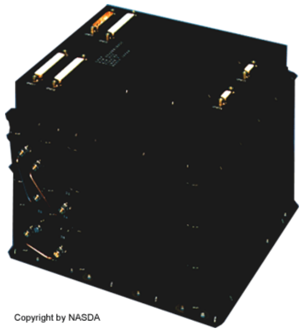
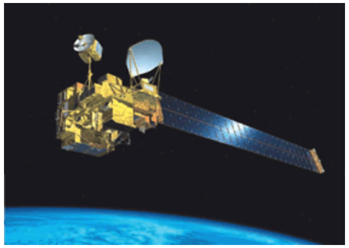




1995 2000 2005 2010 2015


OREX (1994)


ADEOS-2 (2003)


GOSAT (2009)


ASNARO (2014)


ETS-VII (1997)


ALOS (2006)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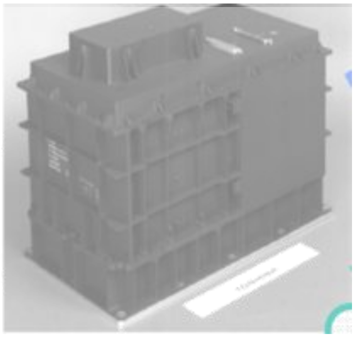
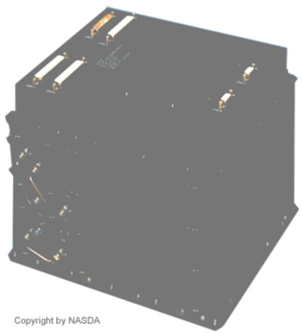
ASTRO-H (2015)

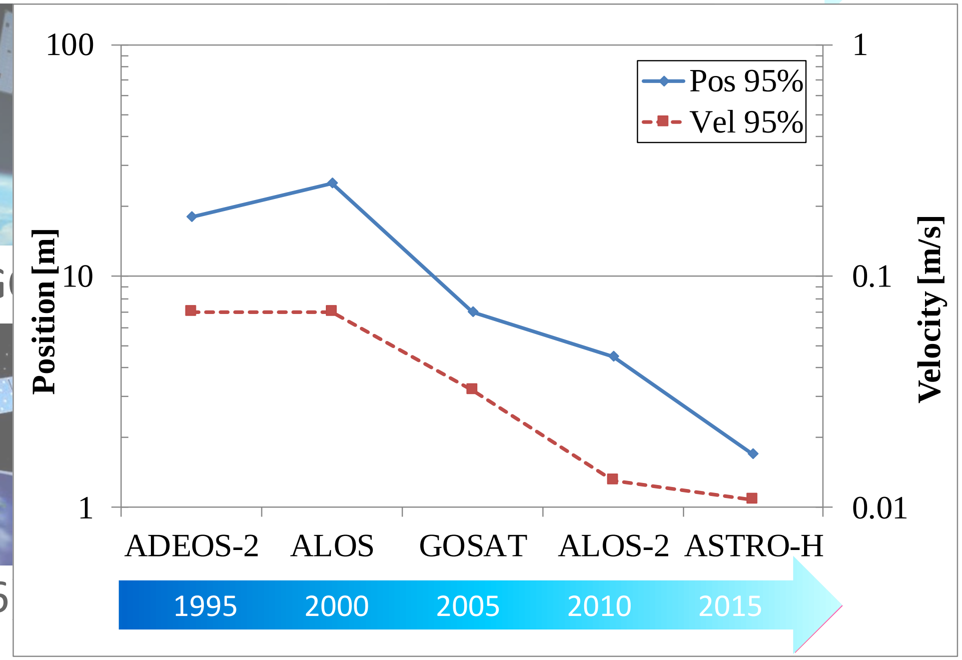
1. History of spaceborne GNSS receiver development in Japan





1995 2000 2005 2010 2015

	OREX	ETS-VII	ALOS	GOSAT	ALOS-2	ASTRO-H
Footprint [cm²]	729	603	447	446	446	209
height [mm]	287	226	111	117	137	155
Mass [kg]	12	7.5	4.8	4.5	5.5	1.95
Max power [W]	50	20	23.4	25	25	19
Type of codes and channel numbers	L1C/A ×5	L1C/A ×6	L1C/A ×6 L2P/Y ×6	L1C/A ×8	L1C/A ×8 L2P/Y ×6 L2C ×8	L1C/A ×36 L2P/Y ×16 L2C ×36
Number of antennas	1	2	1	1	2	3



2. Using GNSS receivers at LEO

- Latest GPS receiver for LEO

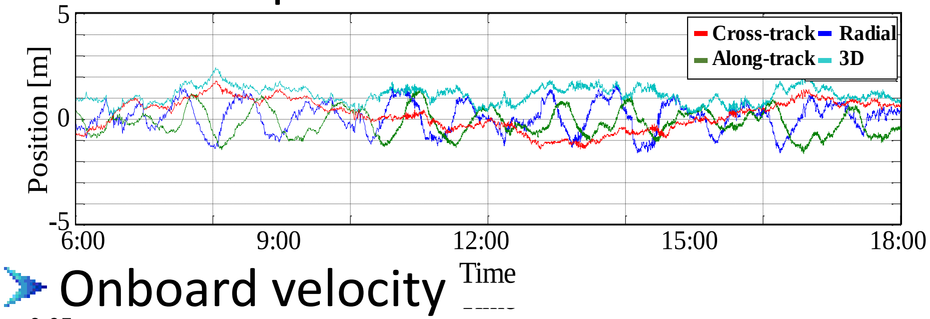
- Features
  - Jointly developed by JAXA and NEC Corp.
  - Light weight, small-size, high power efficiency, and high reliability
  - Three dual-frequency antennas at most (L1 × 3, L2 × 3)
  - Capable to determine the position/velocity within 6 [m] / 3 [cm/s] (RSS 95%)
- Specification @ LEO

Item	Specification
Size/Weight	96×218×155 [mm] / 1.95 [kg]
Power	16 [W] (nominal) / 19 [W] (max)
Number of antennas	Three dual-frequency antennas at most (L1 × 3, L2 × 3)
Number of channels	L1C/A ×36, L2C ×36, L2P(Y) ×16
Onboard L1C/A Navigation Accuracy	Position 6 [m] *
	Velocity 3 [cm/s] *
Onboard L1C/A & L2C Navigation Accuracy	Position 3 [m] *
	Velocity 3 [cm/s] *

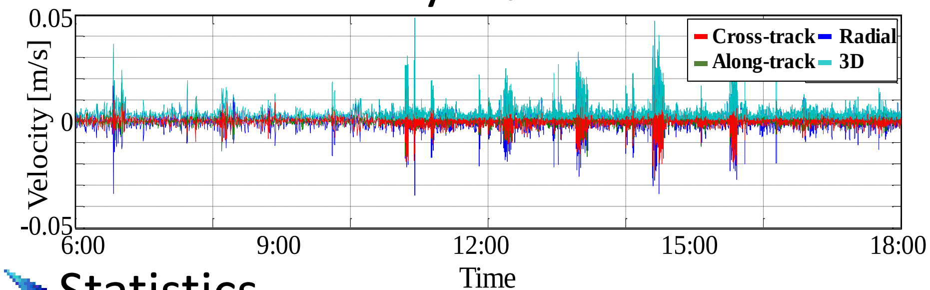
*RSS for 95% of the time

2. Using GNSS receivers at LEO

- Onboard position



- Onboard velocity

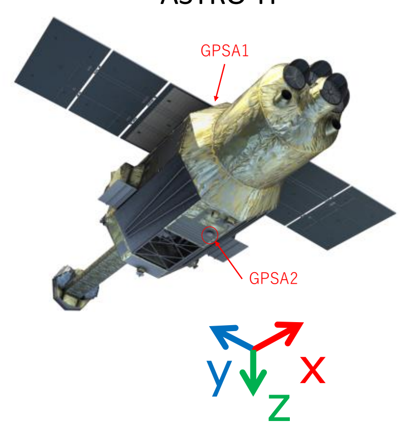


- Statistics

		Radial	Along	Cross	3D RSS (Onboard)	3D RSS (Spec.)
Position error (m)	Average	0.098	-0.201	-0.064	1.1	N/A
	Maximum	1.6	1.6	1.8	2.4	N/A
	Std.	0.72	0.62	0.38	0.38	N/A
	95%	N/A	N/A	N/A	1.7	6
Velocity error (mm/s)	Average	-0.07	-0.01	-0.06	4.0	N/A
	Maximum	38	19	33	48	N/A
	Std.	4.1	2.1	2.7	3.5	N/A
	95%	N/A	N/A	N/A	11	30

- ASTRO-H on board flight data was compared with offline Precise Orbit Determination (POD) products
- The position and velocity errors were 1.7m, 11mm/s (RSS, 95%)
- The results suggested that GPSR has achieved its design goals in terms of position and velocity determination accuracy

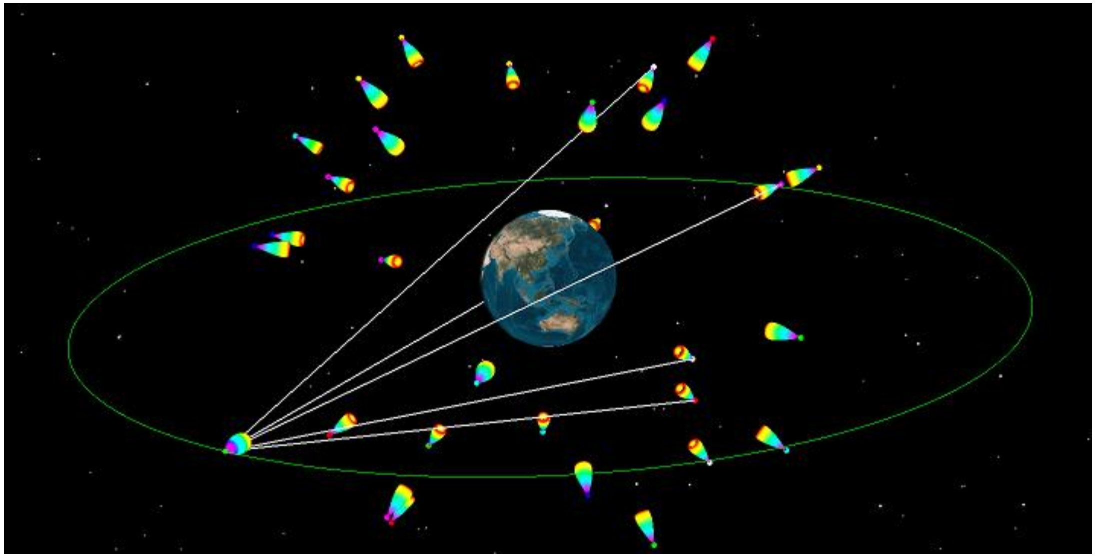
ASTRO-H



Orbit	Inclination: 31˚ Altitude: 575 km
Attitude	Inertially fixed
Antennas	Two antennas on ±Z plane
Onboard navigation filter	Extended Kalman filter using L1 Graphic measurements

3. Using GNSS receivers at GEO

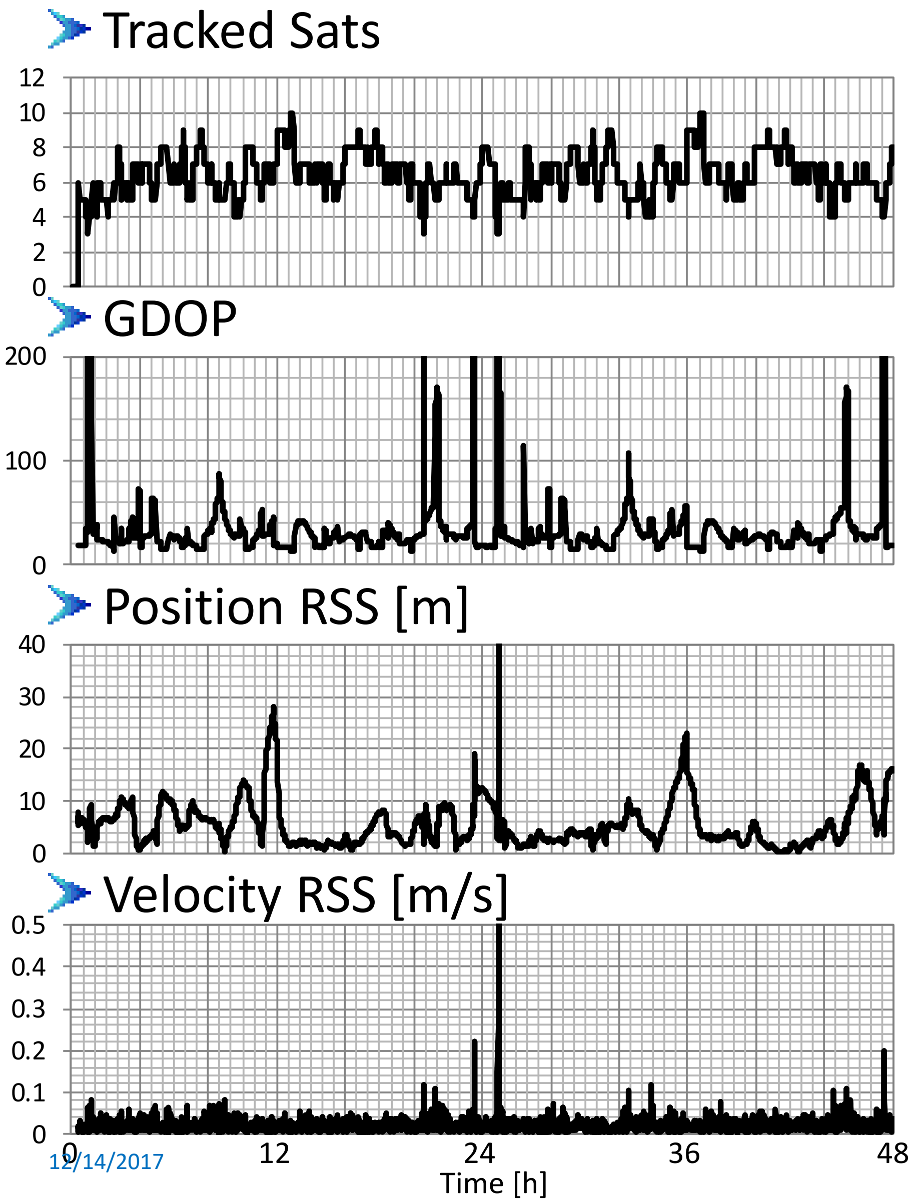
GPS signal acquisition/tracking simulation in GEO



GEO GPSR (almost the same hardware as LEO GPSR)

- GPS receiver for high altitude applications (ex. GEO) is under development taking advantage of the LEO GPSR heritage
- Most of GEO GPSR hardware is inherited from LEO GPSR
- Software for GEO navigation is newly developed to improve the sensitivity and specialized for GEO navigation

3. Using GNSS receivers at GEO



- Ground Experiment by BBM was conducted using GNSS signal simulator with GEO satellite scenarios
- For the most of the simulation time, up to 4 GPS satellites were tracked
- GDOP was deteriorated in case there are only 4 or less satellites visible
- Position RSS was estimated within the error of 10 [m] for the most of the time as long as four or more GPS satellites are available
- Velocity RSS was estimated within the error of 0.1 [m/s]

3. Using GNSS receivers at GEO

Demonstration plan

2014~ → 2019 → 2021

画像提供：三菱電機

LEO (Practical use) 2014~
ASNARO, ASTRO-H, …

- LEO GPSR are used for most of the Japanese satellites as a main source of navigation

GEO (Experiment) 2019
Japanese Data Relay System (JDRS)

- GPSR is planned to be implemented on JDRS, the 1st opportunity to be used at GEO
- GPSR is NOT used for main navigation source, but to be evaluated its performance on orbit

GEO (Practical use) 2021
Engineering Test Satellite-9 (ETS-9)

- GPSR is planned to be used as a main navigation source
- ETS-9 is planned to be controlled autonomously using GPSR onboard navigation solutions

4. Expectations for GNSS signal providers

- In order to enhance the use of GNSS beyond LEO, we, from the viewpoint of GNSS signal users, expect GNSS signal providers
  - to provide sufficient SSV signal information (such as antenna patterns or signal levels including sidelobes, etc.) which is essential for SSV signal utilization of current and future space missions
  - to establish SSV signal specifications in the signal interface specification documents which is essential for dedicated GNSS receiver development
  - to continuously maintain the SSV signal environment for future emerging needs of new space missions using GNSS navigation in high altitude orbits