



SSC07- -1

Miniature GPS Receiver Development and On-Orbit Results

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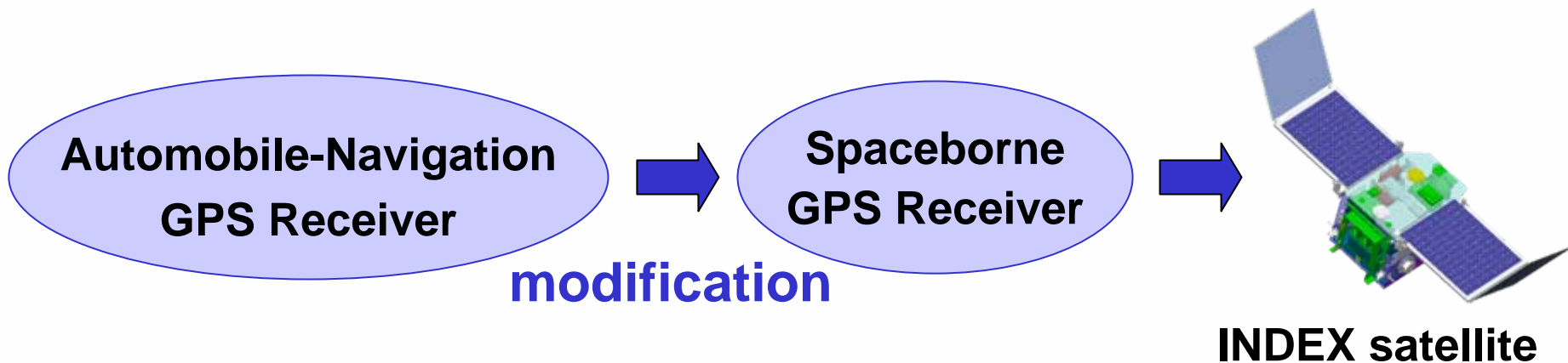
Musashi Institute of Technology, *Soka University, ****Tokyo Denki University,



Introduction

- **GPS (Global Positioning System) receivers**

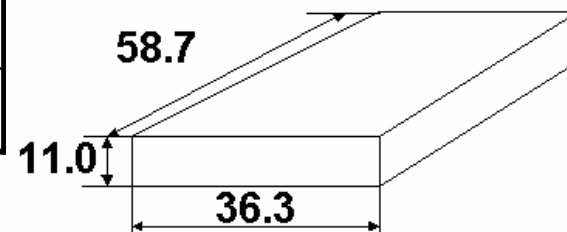
	Spaceborne GPS Receivers	Automobile-Navigation GPS Receivers
Weight	Several kg	< 100 grams
Power	> 10 W	< 1W
Cost	~ \$ 1 million	~ \$ 500

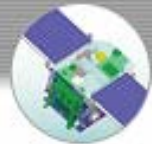




Specification of the selected commercial GPS receiver for automobile-navigation

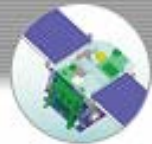
Receiving Channels		8 Channels
RF input	Frequency	L1 : 1.575 GHz C/A
	Sensitivity	-132 dBm
Power supply		DC +5.0 V 180 mA
Power Consumption		0.9 W
Weight		35 g
Size		58.7×36.3×11.0 mm³





Modification- From Commercial to Space GPSR

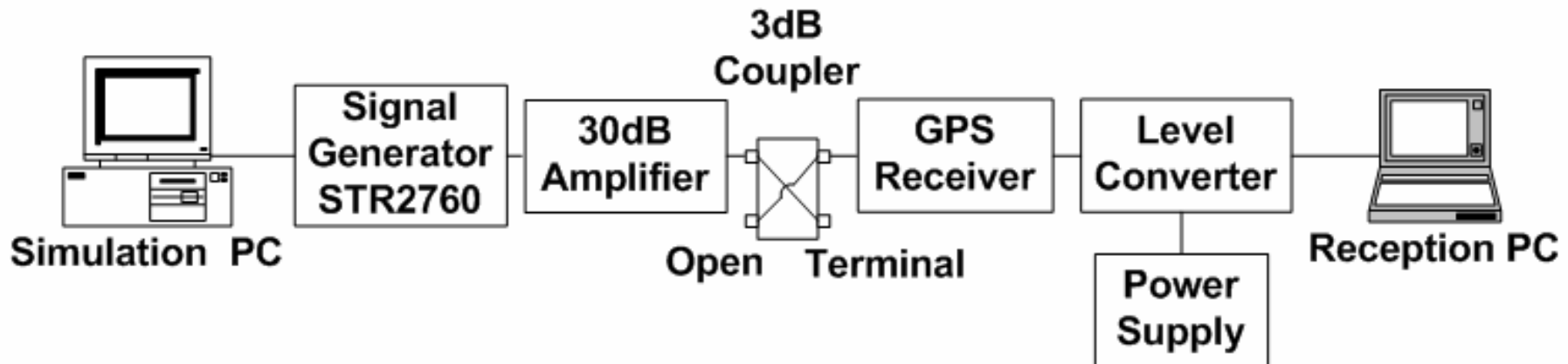
- **Large Doppler Shift in Orbit**
 - ➔ **Expansion of Frequency Scanning Range**
- **Time Tag Error**
 - ➔ **Output of Pseudo range with Accurate Time Tag**



Performance tests with GPS Simulator



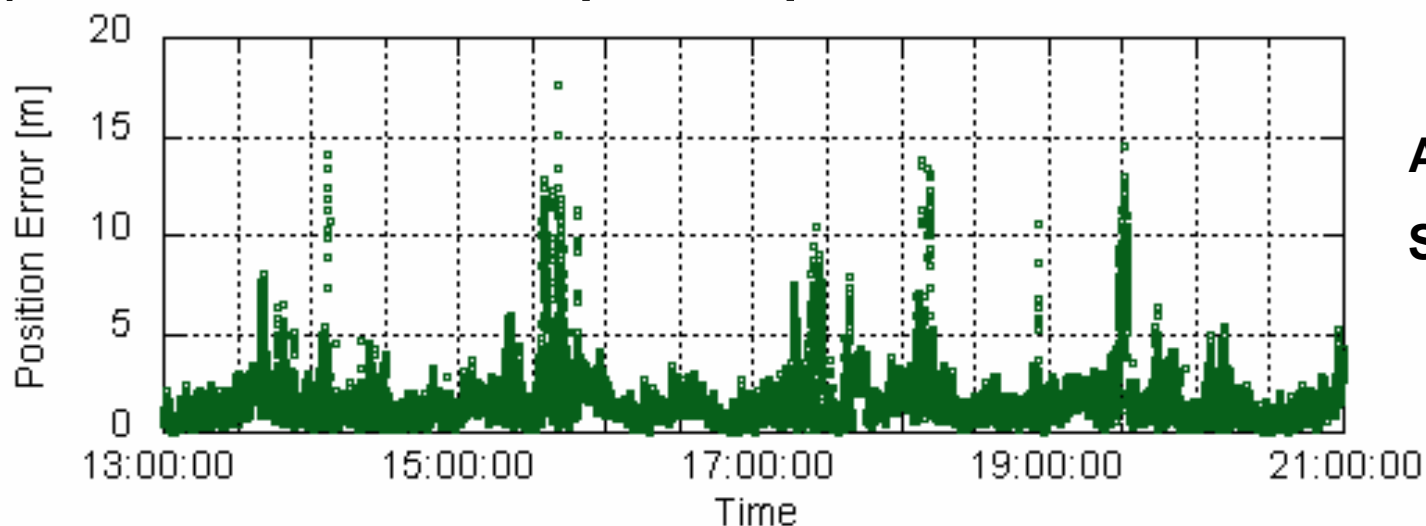
- **GPS Simulator**
 - **STR2760 (SPIRENT Inc.)**
 - **Output Channels : 10 ch**
 - **Signal : L1 (1.575 GHz)**





Position Error of Receiver Measurement GPS Simulator Test

(without error of ionosphere, ephemeris data and satellite clock, etc)



Altitude:690 km

Sun Sync. Orbit

- Position Error of Receiver Measurement : 2 m (RMS)
- PDOP : 2.7 (RMS)
- Receiver Measurement Error : 0.8 m (RMS)
(Position error = $\sigma_{\text{range}} \times \text{PDOP}$)



Estimated Error in Orbit

Error source	Estimated error in orbit (RMS [m])
Ephemeris data	2.1*
GPS satellite clock	2.1*
Ionosphere	5.4**
Receiver measurement	0.8
Total range error	6.2
Position error (PDOP = 2.7)	16.7

* Reference : P.W. Parkinson, "Global Positioning System"

** NATO Standard Agreement STANAG 4294 Issue 1

$$\text{Ionospheric delay} = \frac{82.1 \times \text{TEC}}{F_c^2 \times \left(\sqrt{\sin^2 E + 0.076} + \sin E \right)} \quad \text{TEC} = 1.0 \times 10^{17} \text{ [m}^{-2}\text{]}$$



Radiation Tolerance

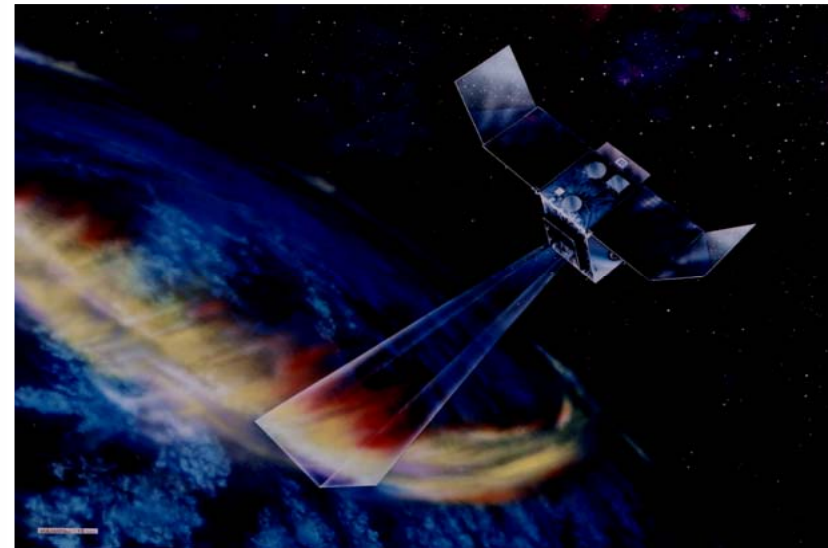
- **Total Dose Radiation test with Co60
20 krad**
- **Radiation test with proton of 30 and 200 MeV
SEL-free
SEU-Once per several days (200 MeV)**



INDEX-REIMEI

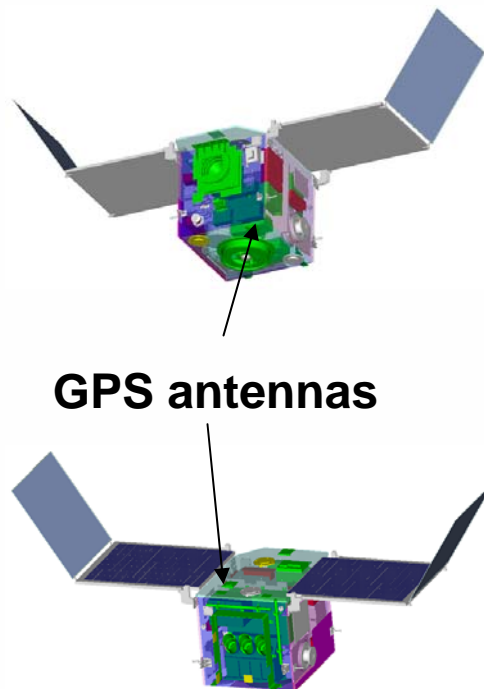
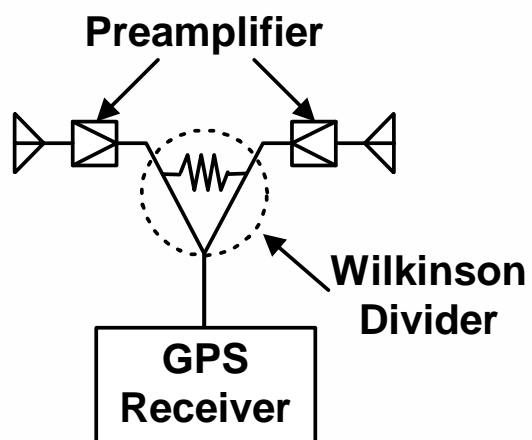
Launched at Aug.2005

Size	72 x 62 x 62 cm ²
Mass	72 kg
Power Supply	160W (MAX)
Science Mission	Observation of Fine Structure of Aurora (w/ Imager and Particle Analyzer)
Engineering Mission	7 Engineering Technology Demonstrations



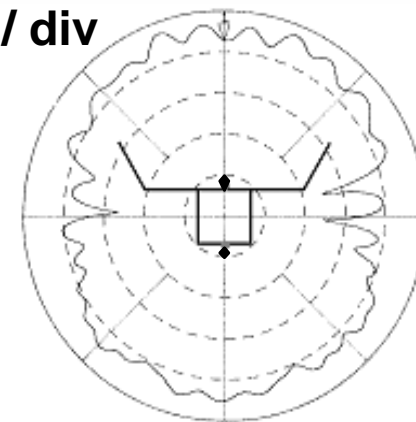


All-Sky GPS Antenna for INDEX



REF : 10 dBi

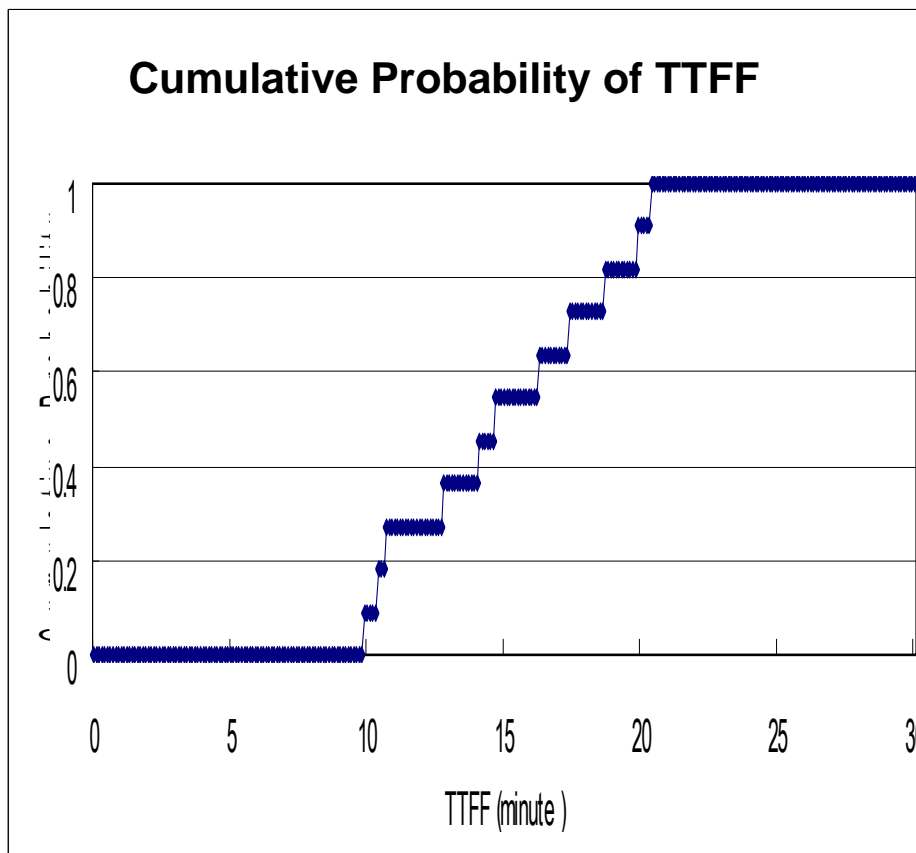
10dB / div



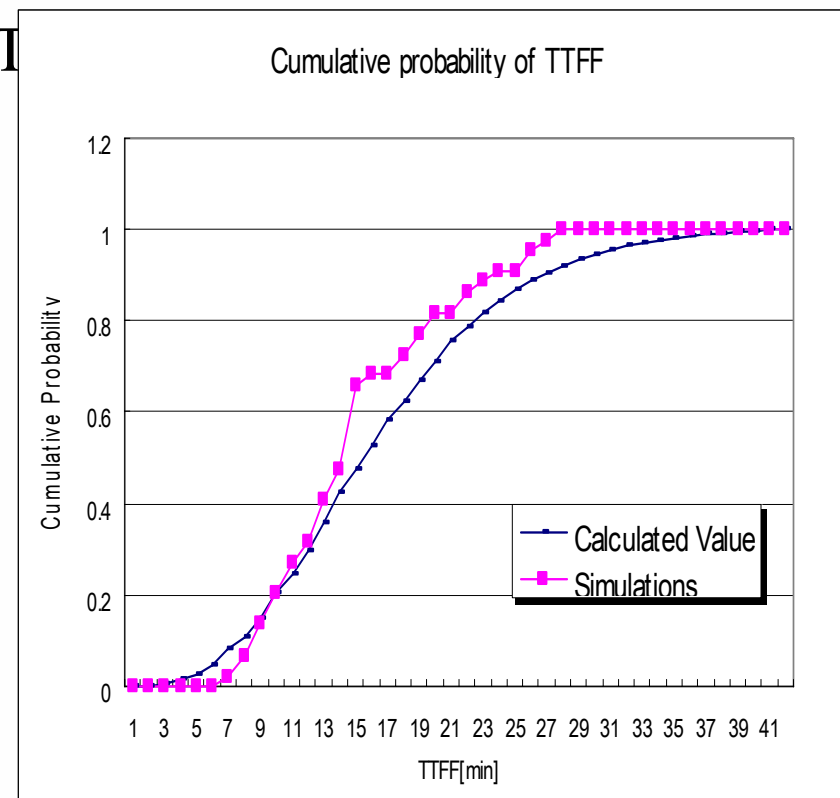


GPS COLD START TIME < 25 minutes

ON ORBIT DATA



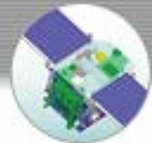
SIMULATION





GPS POSITION ACCURACY

- Conventional Orbit Determination
 - Several 100m Accuracy
 - Orbit Determination with Antenna Angle by JAXA
 - Two Line Element
- Orbit Determination (OD) with GPS Data
Residual Position Error (RPE)
=GPS Data—OD Position
- **RPE with Short-Term (6 0 s) OD**
= **Random Receiver Noise**



Residual Position Error

Error source	Estimated error in orbit (RMS [m])
Ephemeris data	2.1*
GPS satellite clock	2.1*
Ionosphere	5.4**
Receiver measurement	0.8 m

Variation
Time Scale

Orbit Period

Several Hours

Several Minutes

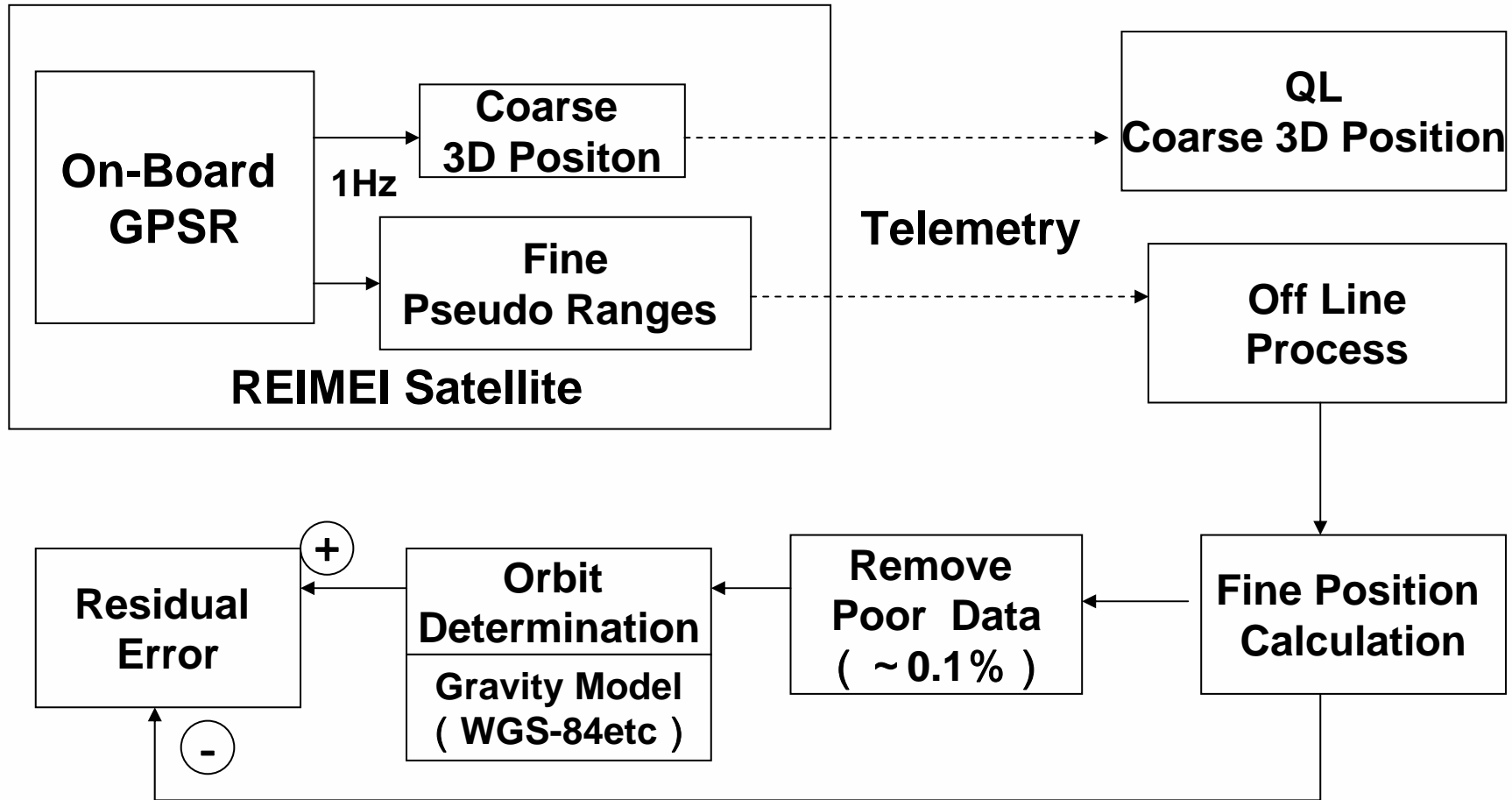
White Noise

Gravity Model Error Air Drag Error	
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Negligible for
Short OD Duration



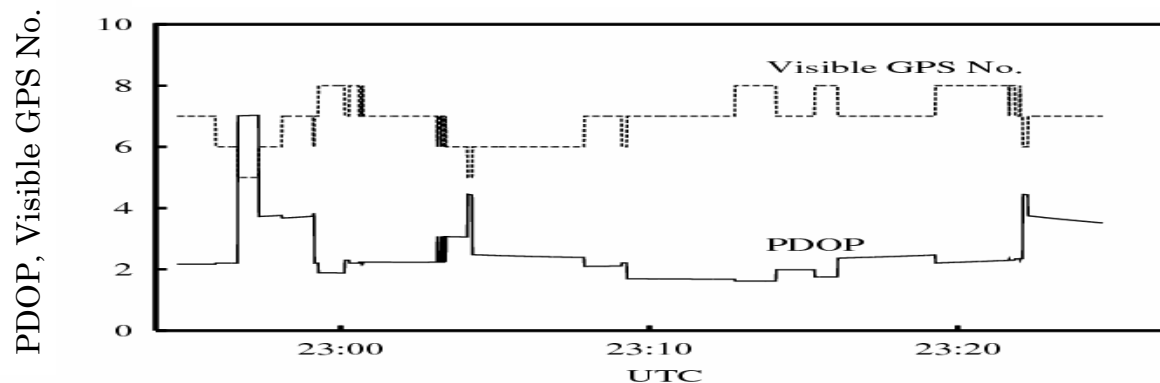
Orbit Determination Process In REIMEI



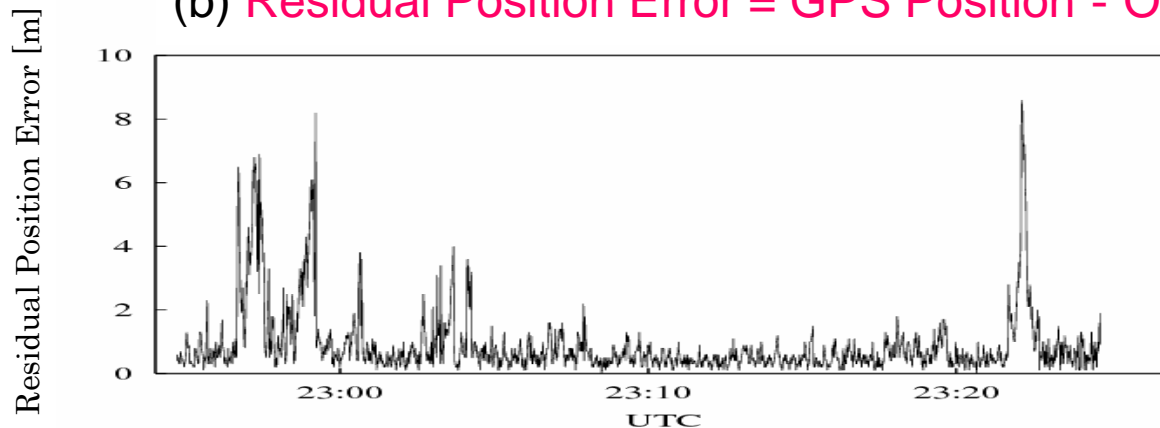


REIMEI GPS Flight Data

(a) PDOP, Visible GPS



(b) Residual Position Error = GPS Position - OD (60sec)



**Error = 1.46m
(rms)**

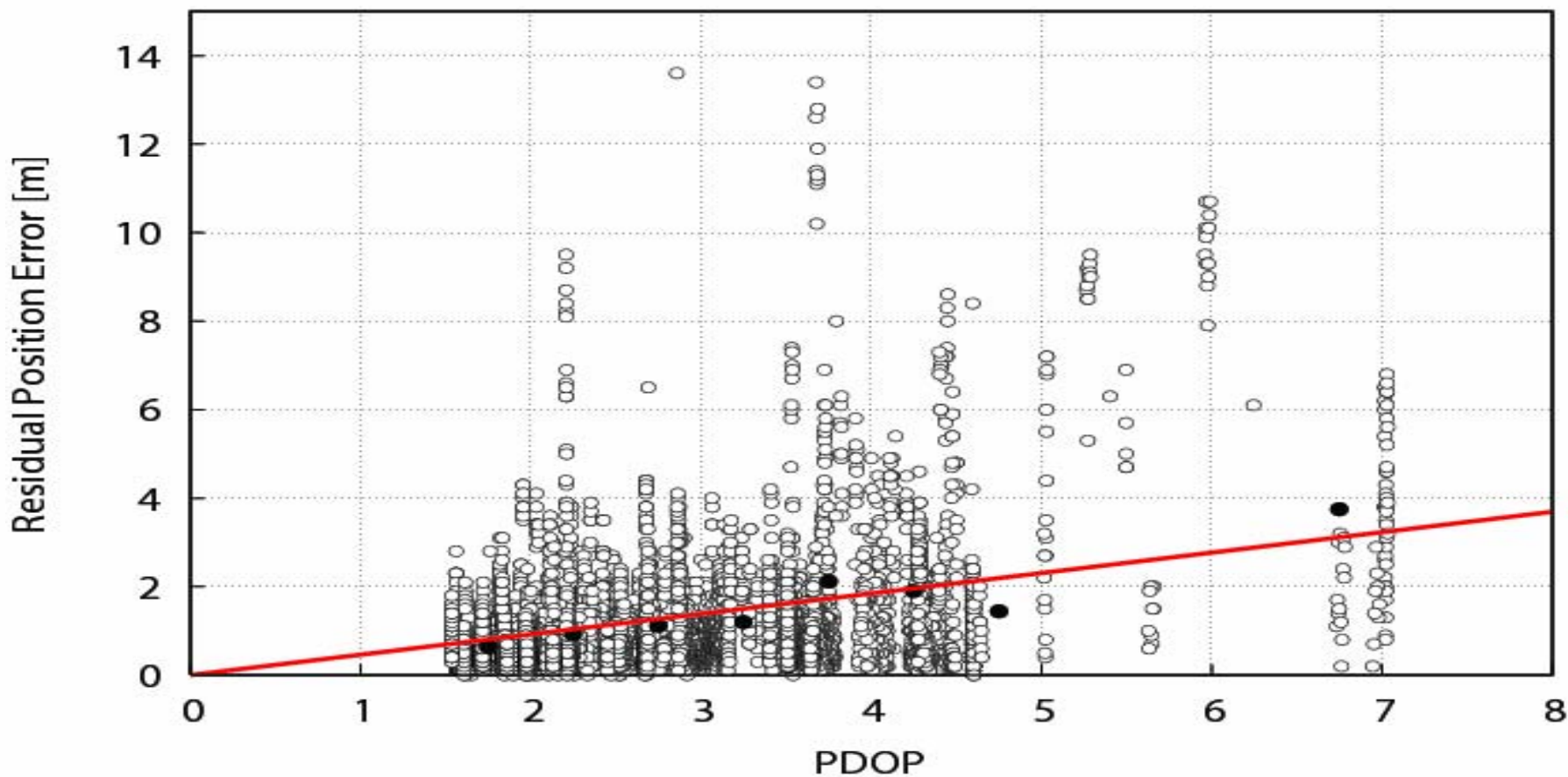
PDOP= 2.7



Position Error (RMS) = PDOP × Range Error (RMS)

Range Error = 0.6m (RMS)

PDOP and Residual Position Error (2006/08/03)

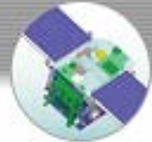




CONCLUSION

- 1 . DEVELOPED MINIATURE SPACE GPSR
BASED UPON CAR NAVIGATION GPSR(35g,\$500)
 - COLD START TTFF < 29 MIN
 - ABSOLUTE ACCURACY < 1.5 m (GPS SIMULATOR)

- 2 . FLIGHT TEST (ISAS/JAXA REIMEI)
 - ORBIT DETERMINATION USING GPS DATA
 - RESIDUAL POSITION ERROR = 1.46m RMS, PDOP=2.7
 - RANGE ERROR = 0.6m RMS
 - GOOD AGREEMENT WITH GPS SIMULATION !



THIS GPSR IS NOW IN COMMERCIAL MARKET

In Commercial Exhibit #47 At Third Floor

Thank you