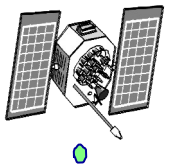
SEJONG UNIVERSITY

우주궤도역학 Term Project #2

Sejong University
Navigation System Lab.

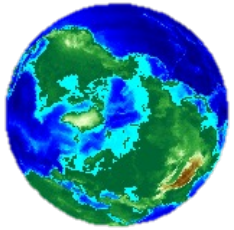
GNSS Overview



GNSS (위성항법시스템, Global Navigation Satellite System)

인공위성에서 방송된 신호를 수신하는 장치를 이용하여 사용자가 자신의 정확한 **시각**과 **3-D 위치 및 속도**를 실시간으로 제공하는 시스템

ex: GPS(미국), Galileo(유럽), GLONASS, ..



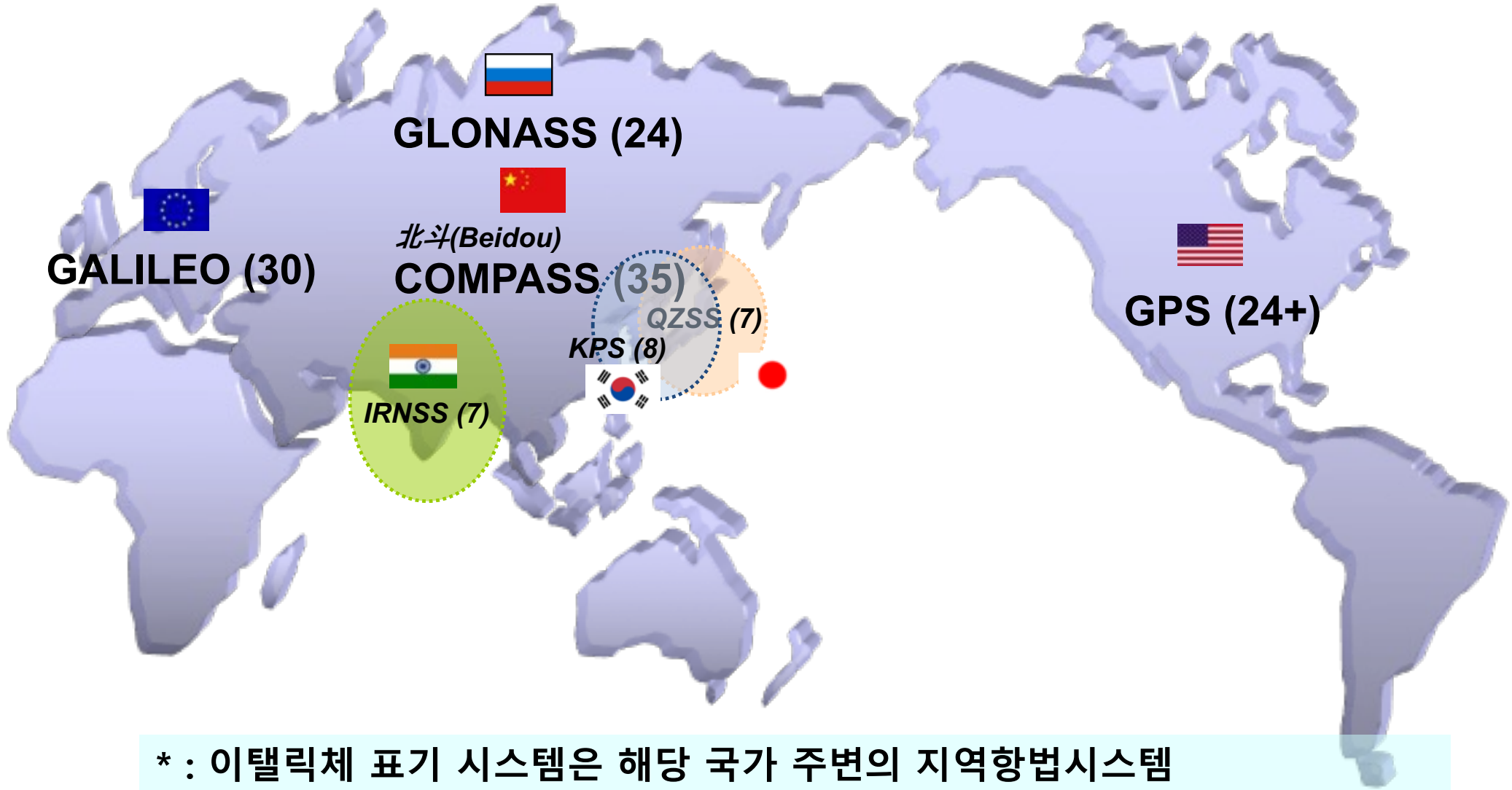
사용자의 시간과 장소, 수량의 제약을 받지 않고 서비스가 가능

GPS(Global Positioning System)란 ?
- 미국의 시스템이나 GNSS을 통칭하거나 GNSS 수신기를 지칭하는데 사용되기도 함

위치 정확도: 20m (GPS), 1m (DGPS), 1cm (RTK)

GNSS Principle - Trigonometry

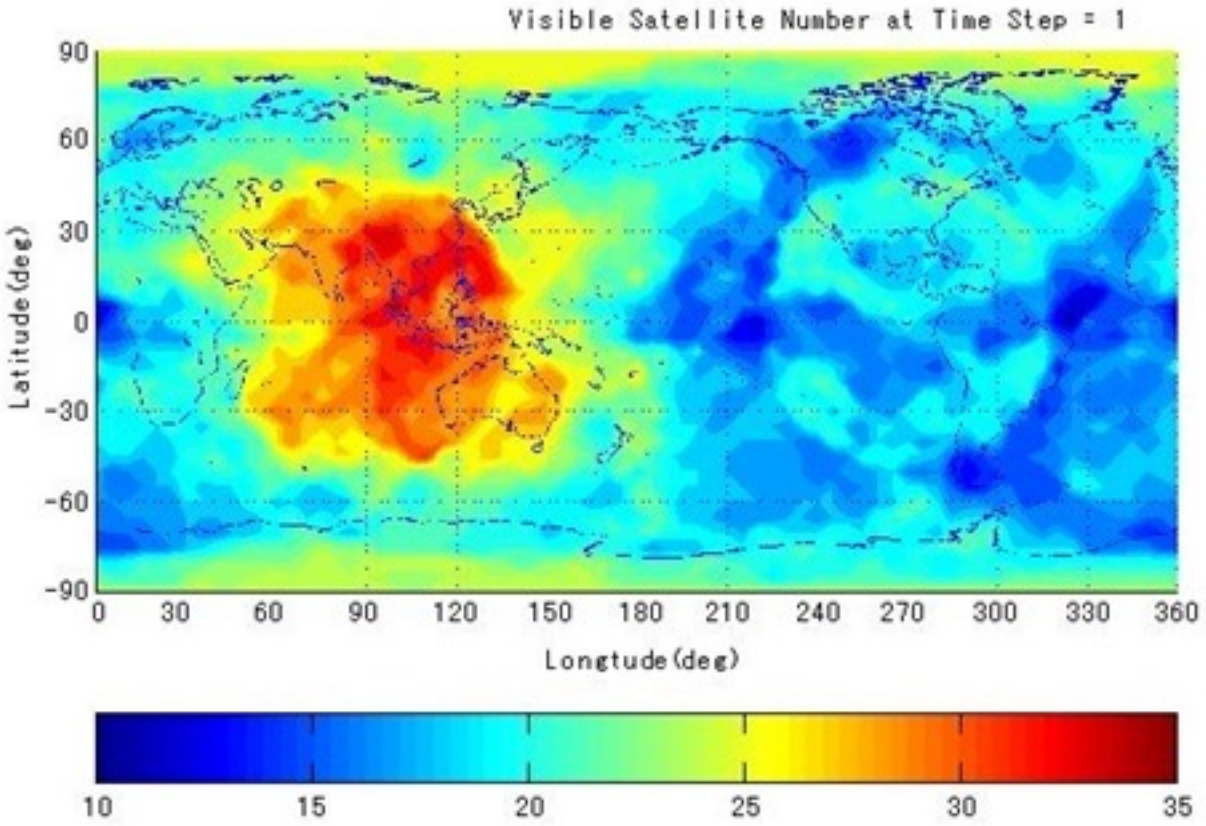
GNSS Status and KPS

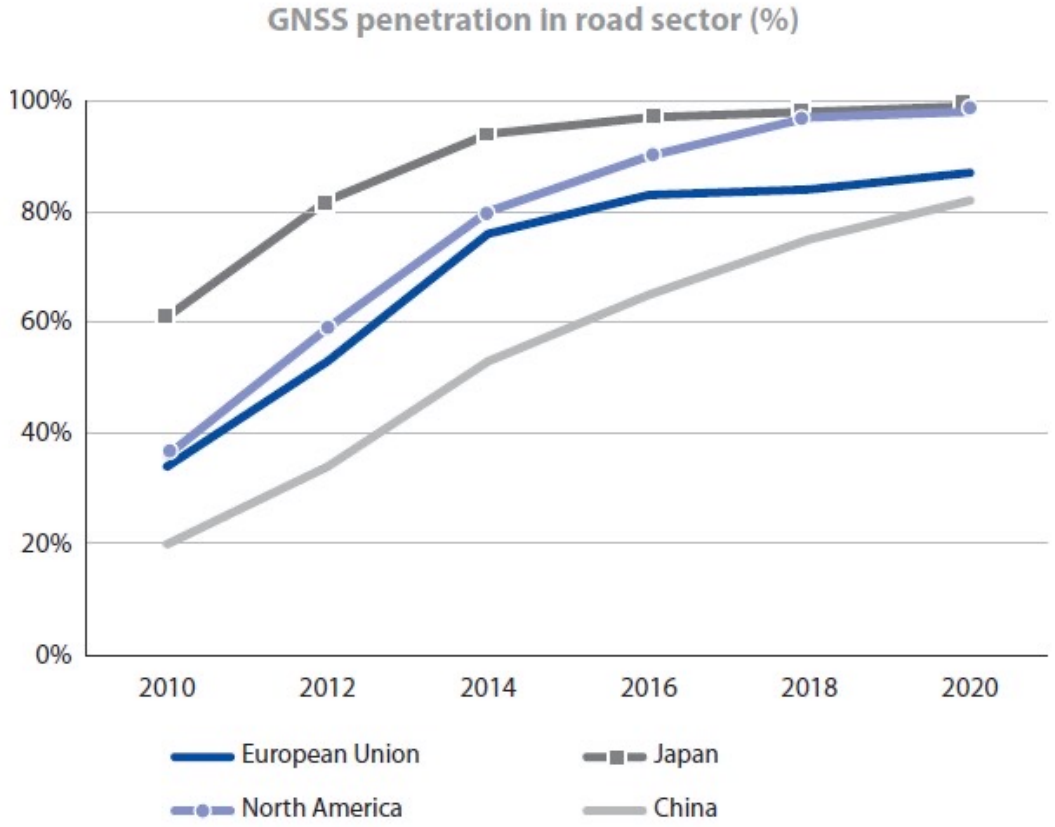


* : 이탤릭체 표기 시스템은 해당 국가 주변의 지역항법시스템

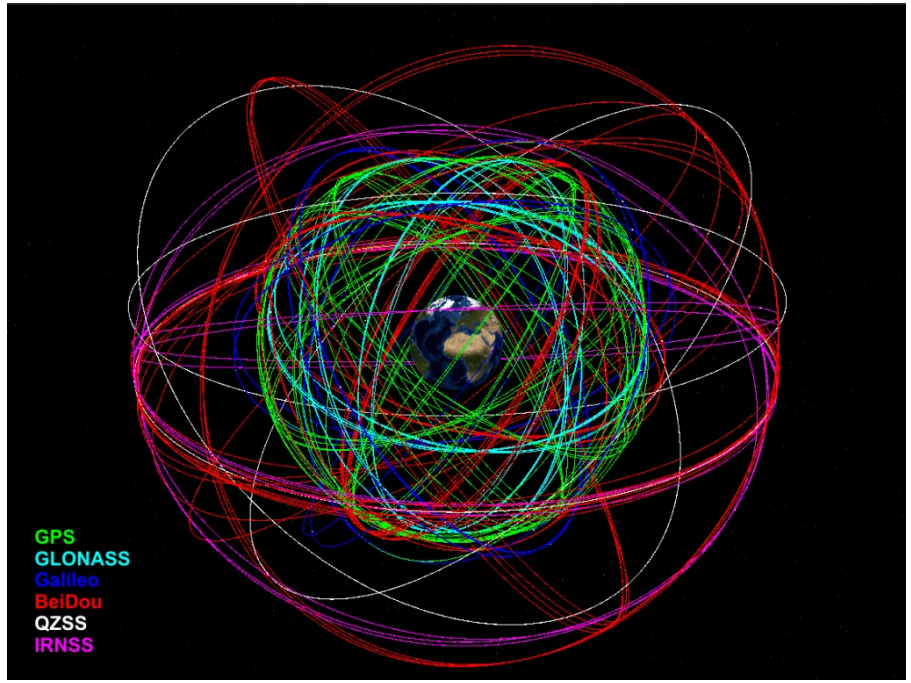
** : () 괄호 안의 숫자는 해당 시스템의 완성 시 기본 항법위성 수

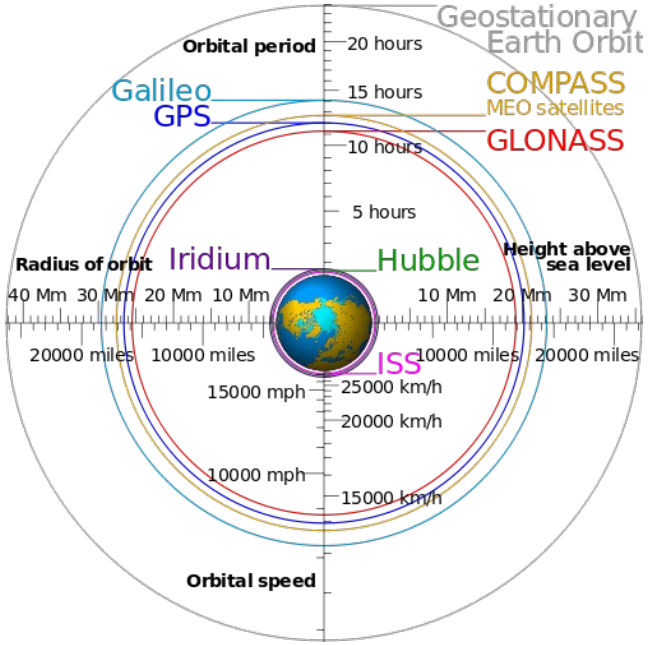
Multi GNSS Hotspot





GNSS Orbits

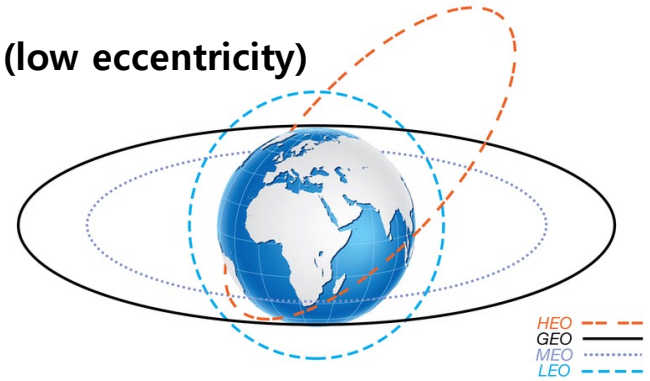




system	GPS	GLONASS	Galileo	Beidou	QZSS	NAVIC(IRNSS)	KPS (TBD)
위성수 (Current)	31	24	23	57	1GEO,3IGSO	4 GSO, 3GEO	-
운영국가	미국	러시아	EU	중국	일본	인도	대한민국(35)
운영범위	전지구	전지구	전지구	전지구	지역	지역	지역
궤도 (Design)	24 MEO	24 MEO	30 MEO	3 GEO + 3 IGSO +24 MEO (30)	4 IGSO, 3 GEO	4 GSO, 3 GEO	5 IGSO, 3 GEO
Semi-major axis	26,560 km	25,508km	29,601km	35,788km (GEO), 35,786 km (IGSO), 21,528km (MEO)	42,164 km (QZO)	36,000 km	TBD

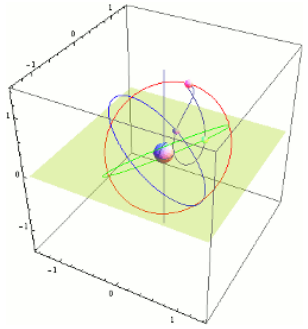
MEO vs IGSO for GNSS

- **MEO (Medium Earth Orbit)**
  - **elliptic but nearly circular (low eccentricity)**
  - **altitude around 20,000km**
  - **speed around 3.3km/s**
  - **global service**

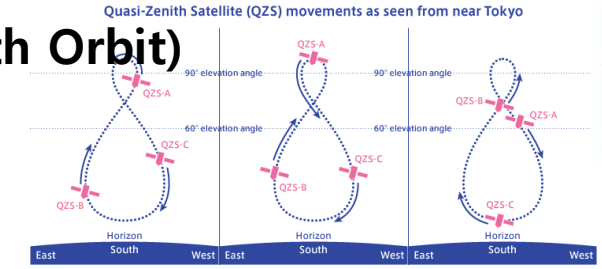


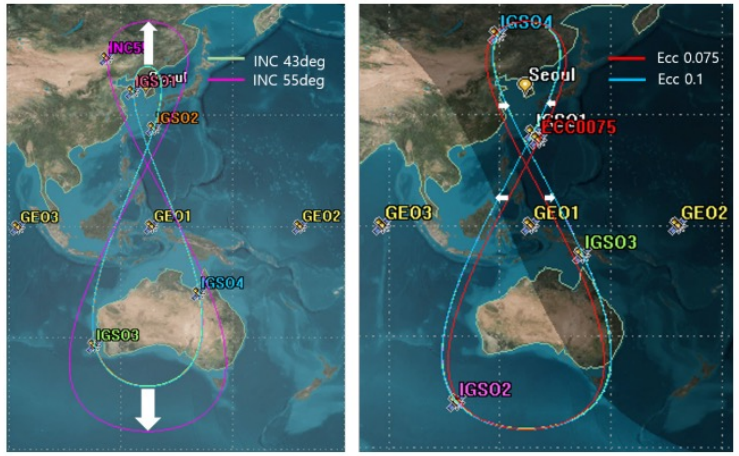
system	GPS	GLONASS	Galileo	Beidou
Number of Satellites (Design)	24+7 MEO	24 MEO	30 MEO	27 MEO+ 3 I GSO + 5 GE O
Orbital Planes	6	3	3	3
Orbital Altitude	20,200km	19,100 km	23,222km	21,528 km
Inclination	55º	64.8º	56º	55º
Period	12hr (11hr 58m)	11hr 15m 44s	14hr 4m 45s	12hr 53m
Repeatability	1day (23hr 56m)	8 days	10 days	7 days

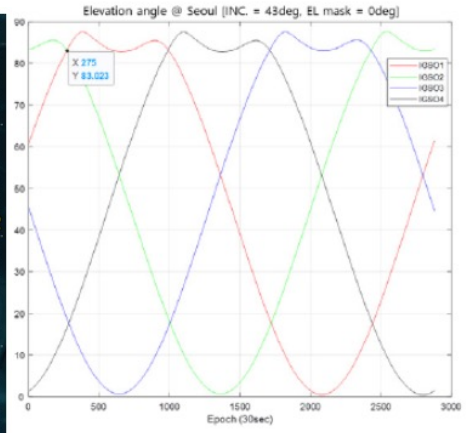
- **IGSO (GEO)**
  - **Earth orbit period : 24 hr**
  - **altitude : 35,786km (approx.)**
  - **GEO : zero inclination (at equator latitude)**
  - **IGSO : a given inclination**



- **EIGSO (ex. QZS, Quasi-Zenith Orbit)**
  - **Eccentric Inclined GEO**
  - **e : 0.075~0.1**







(a) Inclination: 43°, eccentricity: 0.075

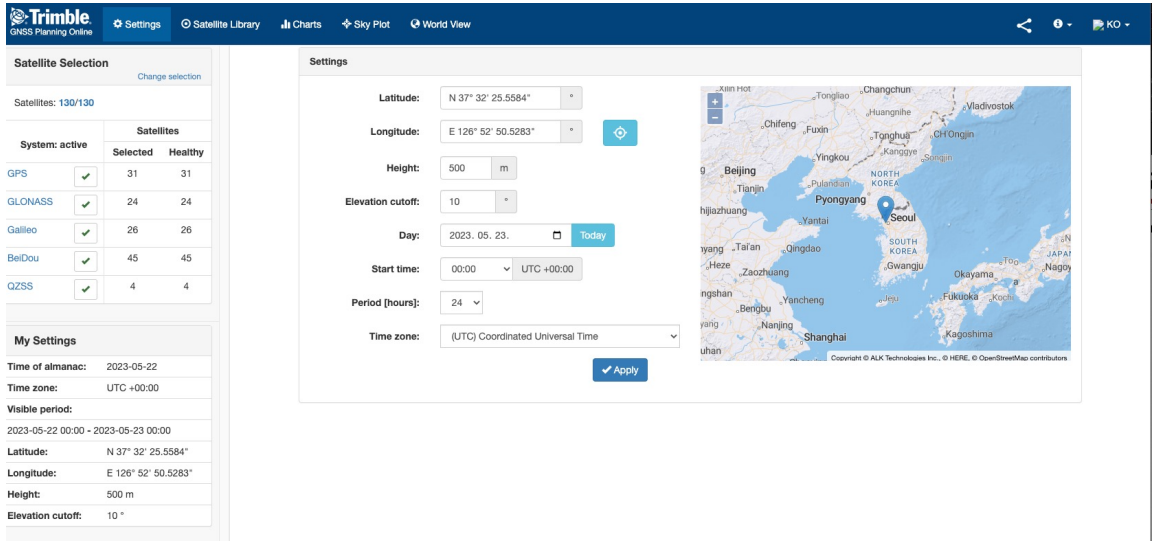
A Study on the Satellite Orbit Design for KPS Requirements, Shin et al

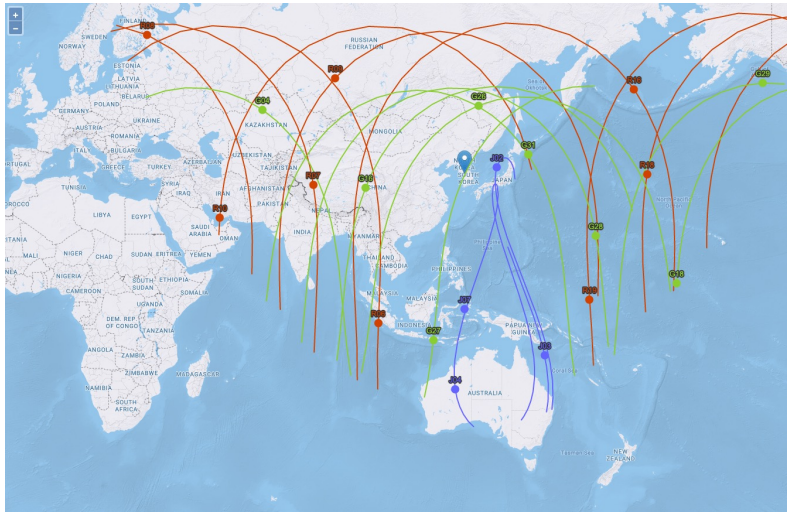
GNSS Status Viewer (example)

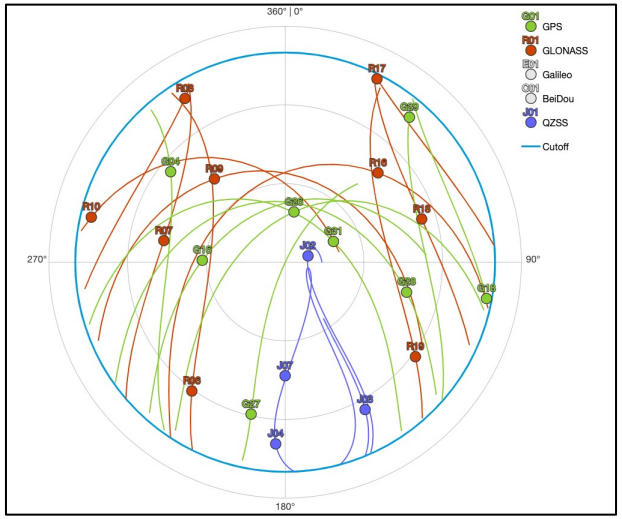
- **Trimble GNSS Planning Online**

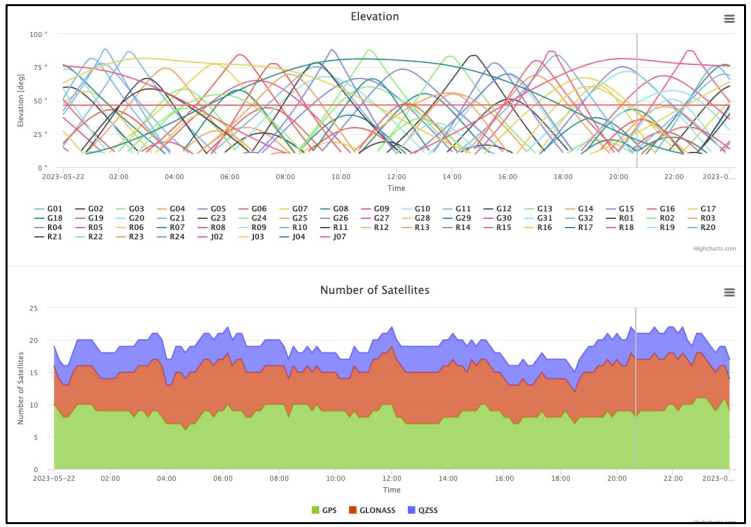
  https://www.gnssplanning.com/#/settings

- **구성**
  - **Configuration**
  - **Ground Tracks (World View)**
  - **Sky Plot**
  - **Chart**









Orbit Parameters for GNSS

Galileo

Satellite	SV ID	Slot	Semi-Major Axis (Km)	Eccentricity	Inclination (deg)	RAAN (deg)[3]	Arg. Perigee (deg)[3]	Mean Anomaly (deg)[3,4]
Satellites in nominal Slots								
GSAT0101	E11	B05	29599.8	0.0	56.0	77.632	0.0	15.153
GSAT0102	E12	B06	29599.8	0.0	56.0	77.632	0.0	60.153
GSAT0103	E19	C04	29599.8	0.0	56.0	197.632	0.0	345.153
GSAT0203	E26	B08	29599.8	0.0	56.0	77.632	0.0	150.153
GSAT0205	E24	A08	29599.8	0.0	56.0	317.632	0.0	135.153
GSAT0206	E30	A05	29599.8	0.0	56.0	317.632	0.0	0.153
GSAT0208	E08	C07	29599.8	0.0	56.0	197.632	0.0	120.153
GSAT0209	E09	C02	29599.8	0.0	56.0	197.632	0.0	255.153
GSAT0210	E01	A02	29599.8	0.0	56.0	317.632	0.0	225.153
GSAT0211	E02	A06	29599.8	0.0	56.0	317.632	0.0	45.153
GSAT0207	E07	C06	29599.8	0.0	56.0	197.632	0.0	75.153
GSAT0212	E03	C08	29599.8	0.0	56.0	197.632	0.0	165.153
GSAT0213	E04	C03	29599.8	0.0	56.0	197.632	0.0	300.153
GSAT0214	E05	C01	29599.8	0.0	56.0	197.632	0.0	210.153
GSAT0215	E21	A03	29599.8	0.0	56.0	317.632	0.0	270.153
GSAT0216	E25	A07	29599.8	0.0	56.0	317.632	0.0	90.153
GSAT0217	E27	A04	29599.8	0.0	56.0	317.632	0.0	315.153

Beidou

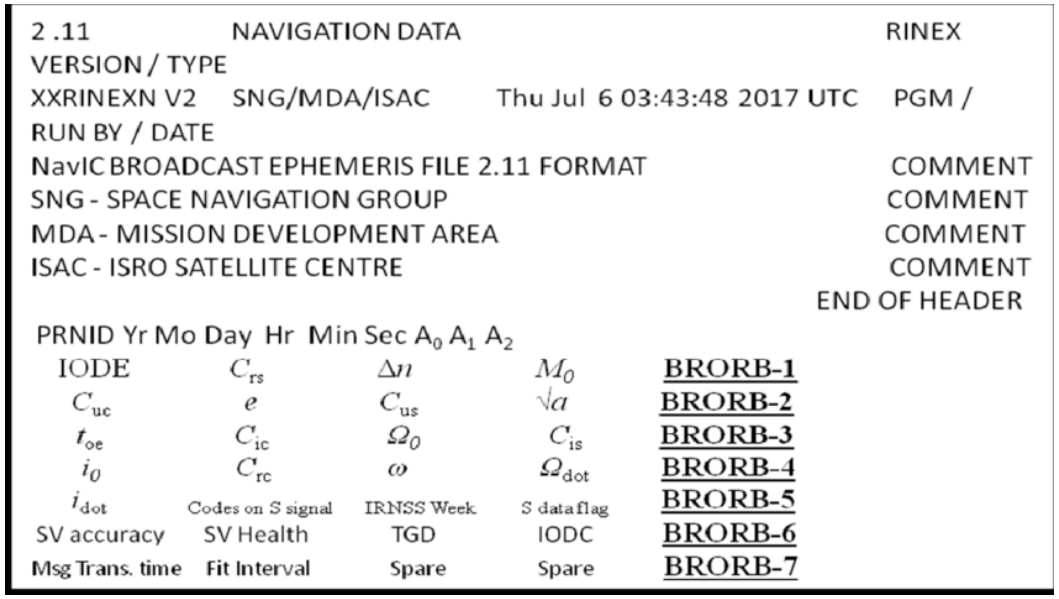
PRN	Eccentricity	Applicable Time (s)	Orbital Inclination (rad)	Rate of Right Ascen (r/s)	SQRT(A) (m 1/2)	Right Ascen at Week (rad)
01	7.8234937973E-004	345600	0.0958150411	-5.0144945881E-010	6493.494226	-3.0206159672E+000
02	9.3543191906E-004	345600	0.0612234274	-5.4430838692E-010	6493.467579	-2.9491427710E+000
03	8.3688960876E-004	345600	0.0612474119	2.1008017925E-009	6493.503147	-2.7837645782E+000
04	6.5489590634E-004	345600	0.0787221629	8.6503603222E-010	6493.398340	-2.9200818332E+000
05	4.0057557635E-004	345600	0.0603796630	2.3679557777E-009	6493.468391	-2.7991196706E+000
06	9.9648673786E-003	345600	0.9443231774	-2.1143737864E-009	6493.741314	1.4873985299E+000
07	7.8559168614E-003	345600	0.8935348032	-1.5543504592E-009	6493.971334	-2.7915007172E+000
08	5.4844868137E-003	345600	1.0395403166	-2.1272314649E-009	6492.801197	-6.3311260748E-001
09	7.2122185957E-003	345600	0.9492108979	-2.1004446348E-009	6493.747835	1.5295654832E+000
10	6.9461365929E-003	345600	0.8952536105	-1.5450643581E-009	6493.035866	-2.7983992463E+000
11	2.2785519250E-003	345600	0.9901911466	-7.0867237619E-009	5282.606829	-1.4791012448E+000
12	1.3834401034E-003	345600	0.9888741458	-7.1338685828E-009	5282.607216	-1.4902967257E+000
13	4.2135684053E-003	345600	1.0006387940	-2.2347359429E-009	6493.669338	-6.5369305897E-001
14	1.1460513342E-003	345600	0.9624626667	-6.4191959567E-009	5282.621925	5.8875155948E-001
16	3.0278427293E-003	345600	0.9597178242	-2.0525854984E-009	6493.518393	1.4755471512E+000
19	5.8755639475E-004	345600	0.9651605758	-6.3234776839E-009	5282.628511	5.8751097569E-001
20	5.3267576732E-004	345600	0.9651569112	-6.4059811205E-009	5282.627695	5.8813228285E-001
21	4.3597316835E-004	345600	0.9644380157	-6.4202674299E-009	5282.628443	5.8990249565E-001
22	4.5954983216E-004	345600	0.9644476388	-6.3791942905E-009	5282.629004	5.8981621420E-001
23	1.9643339329E-004	345600	0.9508712821	-6.6770638408E-009	5282.618404	2.6960637336E+000

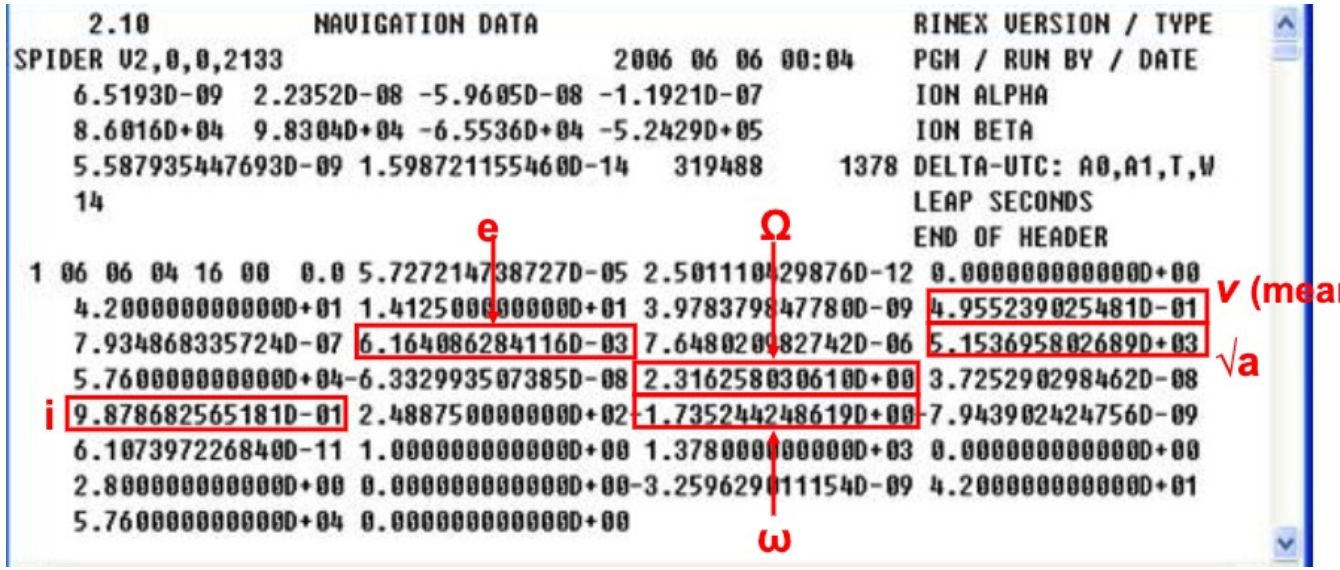
QZSS

Orbit Parameter	Nominal Allocation
Semimajor Axis(A)	42164km
Eccentricity(e)	0.075
Inclination (i)	41 degree
Argument of Perigee(w)	270 degree
RAAN(Ω)	Block I_Q: 117 degree Block II_Q: 117±130 degree
Central Longitude (λ)	136 degree

GNSS Navigation Data

- **RINEX data format**
  - **Receiver INDependent Exchange format**
  - **Basically two file types**
    - **"*.*n" : satellite and ephemeris related data**
    - **"*.*o" : signal observation data like pseudorange, carrier phase, doppler, SNR etc**





GPS Satellite Position Determination (ICD-200M)

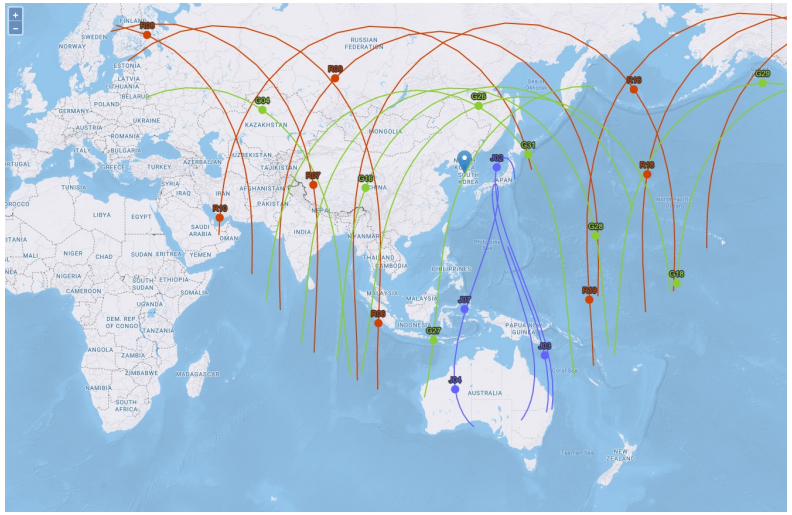
$\mu = 3.986005 \times 10^{14}$ meters^3/sec^2	WGS 84 value of the earth's gravitational constant for GPS user
$\dot{\Omega}_e = 7.2921151467 \times 10^{-5}$ rad/sec	WGS 84 value of the earth's rotation rate
$A = (\sqrt{A})^2$	Semi-major axis
$n_0 = \sqrt{\frac{\mu}{A^3}}$	Computed mean motion (rad/sec)
$t_k = t - t_{oe}$*	Time from ephemeris reference epoch
$n = n_0 + \Delta n$	Corrected mean motion
$M_k = M_0 + nt_k$	Mean anomaly
	Kepler's equation ($M_k = E_k - e \sin E_k$) may be solved for Eccentric anomaly (E_k) by iteration:
$E_0 = M_k$	– Initial Value (radians)
$E_j = E_{j-1} + \frac{M_k - E_{j-1} + e \sin E_{j-1}}{1 - e \cos E_{j-1}}$	– Refined Value, minimum of three iterations, (j=1,2,3)
$E_k = E_j$	– Final Value (radians)
$\nu_k = 2 \tan^{-1}\left(\sqrt{\frac{1+e}{1-e}} \tan \frac{E_k}{2}\right)$	True Anomaly (unambiguous quadrant)

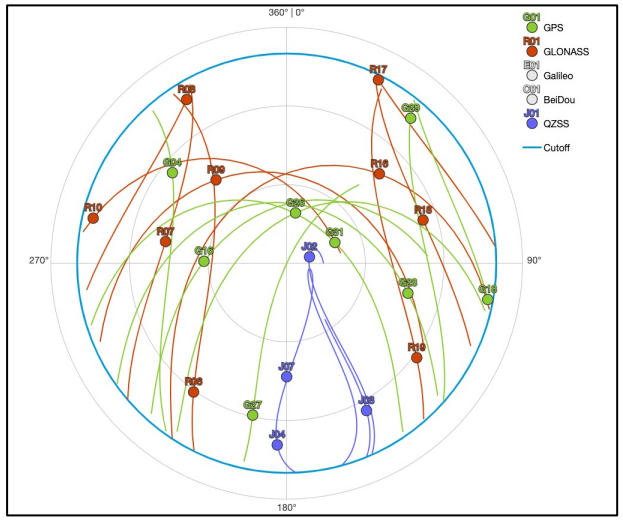
* t is GPS system time at time of transmission, i.e., GPS time corrected for transit time (range/speed of light). Furthermore, t_k shall be the actual total time difference between the time t and the epoch time t_{oe}, and must account for beginning or end of week crossovers. That is, if t_k is greater than 302,400 seconds, subtract 604,800 seconds from t_k. If t_k is less than -302,400 seconds, add 604,800 seconds to t_k.

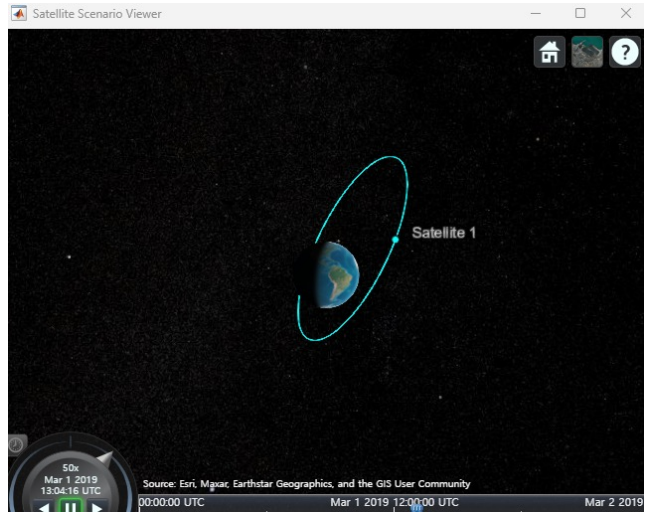
$\Phi_k = \nu_k + \omega$		Argument of Latitude
$\delta u_k = c_{us}\sin 2\Phi_k + c_{uc}\cos 2\Phi_k$	Argument of Latitude Correction	} Second Harmonic Perturbations
$\delta r_k = c_{rs}\sin 2\Phi_k + c_{rc}\cos 2\Phi_k$	Radius Correction	
$\delta i_k = c_{is}\sin 2\Phi_k + c_{ic}\cos 2\Phi_k$	Inclination Correction	
$u_k = \Phi_k + \delta u_k$		Corrected Argument of Latitude
$r_k = A(1 - e \cos E_k) + \delta r_k$		Corrected Radius
$i_k = i_0 + \delta i_k + (\mathrm{IDOT})\, t_k$		Corrected Inclination
$x_k' = r_k \cos u_k$ $y_k' = r_k \sin u_k$		} Positions in orbital plane.
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)\, t_k - \dot{\Omega}_e\, t_{oe}$		Corrected longitude of ascending node.
$x_k = x_k' \cos\Omega_k - y_k' \cos i_k \sin\Omega_k$ $y_k = x_k' \sin\Omega_k + y_k' \cos i_k \cos\Omega_k$ $z_k = y_k' \sin i_k$		} Earth-fixed coordinates.

Processing (Sample)

Navigation Data load → Configuration (GUI) : 시간, 위성, 관측점 등 → 출력 : Ground track, sky view 등 → 사용자 control (GUI)







THANK YOU

For Your Attention