NGA GNSS Division Precise Ephemeris Parameters

Precise Ephemeris Units.

Earth-centered, Earth-fixed Coordinate system	WGS84 (G1762)
Position	x,y,z (km)
Velocity	dx/dt, dy/dt dz/dt (m/s)
GPS time	year, day, hour, minute
Trajectory interval	5 min.
Standard Trajectory	referenced to satellite center of mass
Optional Trajectory	referenced to satellite antenna phase center
Integration step size	300 seconds, reduced to 10 seconds during eclipse boundary crossings

Satellite Clock Parameters Units

Satellite clock Time/Phase offset	μs
Satellite clock Frequency offset	10^{-4} μs/s = parts in 10^{10}
Time interval for parameters	5 min.
Satellite clock events	All events processed as reinitializations

Smoothed Observation Units.

Smoothed range and range difference observations (km) with corrections applied

GPS time of observation	year, day, seconds of day
Standard deviation of observation	km
Coordinate system	WGS84 (G1762)
Station position	x,y,z (m), Epoch 2005.0
Station velocity	dx/dt, dy/dt, dz/dt (m/yr)
Temperature	Celsius
Pressure	millibars
Relative Humidity	percent
Data interval	5 min

The carrier phase is smoothed to the pseudorange for all measurements above 10 deg. These data are collected every 1.5s at NGA and Air Force monitor stations (collected and smoothed with the same algorithm).

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Physical Constants

Earth's semi-major axis (a)	6378.137 km
Lunar radius	1738 km
Solar radius	696000 km
Solar radiation pressure constant	1367.2 W/m^2
Astronomical Unit	149597870.691 km
Earth's Gravitational constant (GM)	398600.4418 km^3/s^2
Sun's Gravitational constant (GM)	132712400000 km^3/s^2
Moon's Gravitational constant (GM)	4902.799186 km^3/s^2
Inverse of the Earth's flattening (1/f)	298.257223563
Earth's angular velocity (precessing frame)	7.2921158553 X 10^{-5} rad/s
Speed of light	299792458.00 m/s
Love's constants	k_{20} = 0.30190 - i0.0
	k_{21} = 0.29830 - i0.00144
	k_{22} = 0.30102 - i0.00130

Corrections Applied to Measurements

Ionospheric delay	2-frequency, 1st order correction
Tropospheric refraction	Saastamoinen hydrostatic and wet zenith delay models and Niell hydrostatic and wet mapping functions
Yaw Bias	JPL yaw bias model for Block II and IIA satellites in eclipse
Periodic relativistic effects	
Satellite antenna offsets	See table below

Satellite Antenna Offset (satellite body centered coordinates)

	Δx (m)	Δy (m)	Δz (m)
Block IIA PRN 18/ SVN 34	0.2794	0.0000	0.9519
Block IIR PRN 02/ SVN 61	-0.0099	0.0061	-0.0820
Block IIR PRN 11/ SVN 46	0.0019	0.0011	1.5141
Block IIR PRN 13/ SVN 43	0.0024	0.0025	1.6140
Block IIR PRN 14/ SVN 41	0.0018	0.0002	1.6137
Block IIR PRN 16/ SVN 56	-0.0098	0.0060	1.6630
Block IIR PRN 19/ SVN 59	-0.0079	0.0046	-0.0180
Block IIR PRN 20/ SVN 51	0.0022	0.0014	1.6140
Block IIR PRN 21/ SVN 45	0.0023	-0.0006	1.5840
Block IIR PRN 22/ SVN 47	0.0018	-0.0009	0.0598
Block IIR PRN 23/ SVN 60	-0.0088	0.0035	0.0004
Block IIR PRN 28/ SVN 44	0.0018	0.0007	1.5131
Block IIR-M PRN 05/ SVN 50	0.0029	-0.0001	-0.0167
Block IIR-M PRN 07/ SVN 48	0.0013	0.0003	0.0006
Block IIR-M PRN 12/ SVN 58	-0.0102	0.0059	-0.0936
Block IIR-M PRN 15/ SVN 55	-0.0100	0.0058	-0.0123
Block IIR-M PRN 17/ SVN 53	-0.0100	0.0060	-0.1008
Block IIR-M PRN 29/ SVN 57	-0.0101	0.0059	-0.0151
Block IIR-M PRN 31/ SVN 52	0.0016	0.0003	-0.0575
Block IIF PRN 01/ SVN 63	0.3910	0.0000	1.0910
Block IIF PRN 03/ SVN 69	0.3950	0.0003	1.0907
Block IIF PRN 06/ SVN 67	0.3947	-0.0010	1.0917
Block IIF PRN 08/ SVN 72	0.3962	-0.0003	1.0856
Block IIF PRN 09/ SVN 68	0.3955	-0.0020	1.0922
Block IIF PRN 10/ SVN 73	0.3962	-0.0013	1.0831
Block IIF PRN 24/ SVN 65	0.3920	0.0020	1.0930
Block IIF PRN 25/ SVN 62	0.3920	0.0020	1.0930
Block IIF PRN 26/ SVN 71	0.3949	-0.0011	1.0927
Block IIF PRN 27/ SVN 66	0.3914	0.0003	1.0904
Block IIF PRN 30/ SVN 64	0.3952	-0.00080	1.0904
Block IIF PRN 32/ SVN 70	0.3966	-0.00020	1.0843
Block III PRN 04/ SVN 74	0.003785	-0.018085	1.2324

Forcing Models

NGA uses IAU Resolutions on Astronomical Constants, Time Scales, and the Fundamental Reference Frame (1976-1980)

Gravitational	
	Normalized EGM08 (2008) Earth gravity model truncated at degree 12 and order 12
	Solar, Lunar and Planetary gravity using the DE403 ephemerides, J2000 epoch, and IAU Resolutions
	International Earth Rotation and Reference Systems Service (IERS) Solid Earth tides – Tech Note 36
Non-gravitational	
	Radiation Pressure: The JPL TJPLXYZ03 - II/IIA version model for Block II and IIA satellites The JPL TJPLXYZ03 - IIR version model for Block IIR satellites The Lockheed-Martin Lookup Table - for Block IIF and III satellites
Kinematic	
	Luni-solar and planetary precession (IAU Resolutions, as above)
	Nutation (IAU Resolutions, as above)
	Earth rotation (IAU Resolutions, as above)
	Polar Motion (using NGA initial values generated the week before the orbit fit) + diurnal and semi-diurnal effects
	UT1-UTC (using NGA initial values generated the week before the orbit fit) + Zonal tide effects + diurnal and semi-diurnal effects

Celestial to Terrestrial Reference Translation Orbit Estimation Method

Kalman Filter/RTS Smoother (Square Root Information implementation)

Initial conditions	Previous fit
Satellite state vector in element form at trajectory epoch	Semi-major axis Eccentricity * sin(argument of perigee) Eccentricity * cos(argument of perigee) Inclination Mean anomaly + argument of perigee Right ascension of the ascending node
Satellite clock parameters	Time and frequency offsets
Monitor station clock parameters (excluding master station)	Time and frequency offsets
Polar motion parameters	Pole position and pole rate along Greenwich meridian Pole position and pole rate along 90^{o} west meridian Rate of change and acceleration of UT1-UTC
Satellite radiation pressure parameters	Radiation pressure scale and Y-axis acceleration
Tropospheric refraction	One stochastic zenith delay parameter per station

Model Uncertainties and Process Noise

Minimum range observation sigma (All Stations)	Pseudorange 1m
	Carrier Phase 0.01m
Tropospheric refraction variance rate	8.0277778 X 10^{-8} m^2/s
Radiation pressure (each satellite)	Decorrelation time 14,400 s Steady state scale sigma 0.05 Y- AXIS Bias 0.5 nm/s^2

Satellite Clock Estimation Method

Kalman Filter/RTS Smoother (Square Root Information implementation)
Orbit solutions from above method are held fixed for satellite clock estimation.

Solution Parameters

Satellite clock parameters	Time and Frequency offset
Monitor station clock parameters (excluding master station)	Time and Frequency offset
Tropospheric refraction	One stochastic zenith delay parameter per station

Station Clock White Noise Spectral Densities

NGA stations (except USNO) and Air Force stations (except Colorado Springs)	Time offset	1.944 X 10^{-21} s^2/s
	Frequency offset	4.444 X 10^{-32} s^2/s^3
NGA station at USNO and Air Force station at Colorado Springs	Time offset	1.380 X 10^{-22} s^2/s
	Frequency offset	4.444 X 10^{-32} s^2/s^3
IGS stations with Cesium	Time offset	3.456 X 10^{-21} s^2/s
	Frequency offset	4.444 X 10^{-32} s^2/s^3

Satellite Clock White Noise Spectral Densities

Satellite Block IIR/IIF Rubidium clocks	Time offset	1.058 X 10^{-22} s^2/s
	Frequency offset	1.110 X 10^{-31} s^2/s^3
	Frequency drift	1.110 X 10^{-43} s^2/s^5
Satellite Block II/IIA Rubidium clocks	Time offset	1.944 X 10^{-21} s^2/s
	Frequency offset	1.110 X 10^{-31} s^2/s^3
	Frequency drift	1.110 X 10^{-43} s^2/s^5
Satellite Block III Rubidium clocks	Time offset	1.058 X 10^{-22} s^2/s
	Frequency offset	1.110 X 10^{-31} s^2/s^3
	Frequency drift	1.110 X 10^{-43} s^2/s^5
Satellite 'Noisy' Rubidium clocks	Time offset	1.33 X 10^{-20} s^2/s
	Frequency offset	1.110 X 10^{-31} s^2/s^3
	Frequency drift	1.110 X 10^{-43} s^2/s^5

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