The National Geodetic Survey Standard GPS Format SP3

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INTRODUCTION

Why do we need standardized orbit formats? Standard orbit formats provide many advantages, the most obvious being orbit exchange. ASCII and binary formats both satisfy this function, but ASCII does it with greater generality because binary formats are computer operating system dependent.

The NGS standard GPS orbit format SP1 was introduced in Remondi (1985). After a few years of use, it was realized that enhancements would eventually be required. The "orbit type," the coordinate system, and the GPS week associated with the first epoch of the ephemeris file were added in a manner that did not impact the formats and existing software.

A more serious omission of the initial NGS orbit format was the satellite clock corrections. This omission reflected an earlier belief that all geodetic applications could be accomplished in differential mode. Today we realize that standard formats serve a wider community and include those who find it inconvenient to operate in a differential mode. A user can operate in single-receiver or navigation mode based on the broadcast message. However, the user can get more accurate (post-processed) results if the precise orbital data and the associated satellite clock corrections, which were determined simultaneously with those precise orbits, are available. This becomes even more valuable when the broadcast orbit and clock information are intentionally degraded.

Thus, a new NGS orbit format was proposed in Remondi (1989), and modified and adopted in Remondi (1991). This format is similar to the original NGS orbit format, but comprises positional and satellite clock correction data. Furthermore, other changes were proposed which allow more flexibility with regard to enhancements. This summary document combines the specifications and enhancements discussed in Remondi (1989) and Remondi (1991), with examples for the benefit of the user.

SP3

In this document the NGS orbital format SP3 (Standard Product # 3) for Global Positioning System (GPS) satellites is discussed (see examples 1 and 2). The major addition to earlier formats is the satellite clock correction information which is

computed simultaneously with the orbits. The basic format is a position and clock record; a second, optional, record contains velocities and clock rates-of-change. The Position Record Flag, P, in line one indicates that no velocities are included. The Velocity Record Flag, V, in line one indicates that at each epoch, and for each satellite, a satellite velocity and clock rate-of-change has been computed. The SP3 format has been designed such that satellites other than GPS could be described as well.

Note: All times referred to in this document are GPS times, even when they are represented as Gregorian or Modified Julian Dates. Thus, information for conversion of GPS time to Coordinated Universal Time (UTC) is not provided as part of the SP3 format.

! Standard Product #3 ASCII SP3 Format Version "a"
(refer to example given in figure 1)

SP3 First Line

Columns 1-2	Version Symbol	#a
Column 3	Pos or Vel Flag	P or V
Columns 4-7	Year Start	1994
Column 8	Unused	_
Columns 9-10	Month Start	12
Column 11	Unused	_
Columns 12-13	Day of Month St	17
Column 14	Unused	_
Columns 15-16	Hour Start	_0
Column 17	Unused	_
Columns 18-19	Minute Start	_0
Column 20	Unused	_
Columns 21-31	Second Start	_0.00000000
Column 32	Unused	_
Columns 33-39	Number of Epochs	_____96
Column 40	Unused	_
Columns 41-45	Data Used	____d
Column 46	Unused	_
Columns 47-51	Coordinate Sys	ITR92
Column 52	Unused	_
Columns 53-55	Orbit Type	FIT
Column 56	Unused	_
Columns 57-60	Agency	_NGS

SP3 Line Two

Columns 1-2	Symbols	##
Column 3	Unused	_
Columns 4-7	GPS Week	_779
Column 8	Unused	_
Columns 9-23	Seconds of Week	518400.00000000
Column 24	Unused	_
Columns 25-38	Epoch Interval	__900.00000000
Column 39	Unused	_
Columns 40-44	Mod Jul Day St	49703
Column 45	Unused	_
Columns 46-60	Fractional Day	0.0000000000000

SP3 Line Three

Columns 1-2	Symbols	+_
Column 3-4	Unused	__
Columns 5-6	Number of Sats	25
Column 7-9	Unused	__

```
Columns 10-12       Sat #1 Id        __1
Column  13-15       Sat #2 Id        __2
       *
       *
       *
Columns 58-60       Sat #17 Id      _22

SP3 Line Four

Columns 1-2         Symbols          +_
Columns 3-9         Unused           _______
Columns 10-12       Sat #18 Id       _23
Columns 13-15       Sat #19 Id       _24
       *
       *
       *
Columns 58-60       Sat #34 Id       __0


SP3 Line Five

Columns 1-2         Symbols          +_
Columns 3-9         Unused           _______
Columns 10-12       Sat #35 Id       __0
Columns 13-15       Sat #36 Id       __0
       *
       *
       *
Columns 58-60       Sat #51 Id       __0


SP3 Line Six

Columns 1-2         Symbols          +_
Columns 3-9         Unused           _______
Columns 10-12       Sat #52 Id       __0
Columns 13-15       Sat #53 Id       __0
       *
       *
       *
Columns 58-60       Sat #68 Id      __0


SP3 Line Seven

Columns 1-2         Symbols          +_
Columns 3-9         Unused           _______
Columns 10-12       Sat #69 Id       __0
Columns 13-15       Sat #70 Id       __0
       *
       *
       *
Columns 58-60       Sat #85 Id       __0


SP3 Line Eight

Columns 1-2         Symbols          ++
Columns 3-9         Unused           _______
Columns 10-12       Sat #1 Accuracy  __7
Columns 13-15       Sat #2 Accuracy  __6
       *
       *
       *
Columns 58-60       Sat #17 Accuracy __5
```

```
SP3 Line Nine

Columns 1-2         Symbols          ++
Columns 3-9         Unused           _______
Columns 10-12       Sat #18 Accuracy __5
Columns 13-15       Sat #19 Accuracy __5
       *
       *
       *
Columns 58-60       Sat #34 Accuracy __0


SP3 Line Ten

Columns 1-2         Symbols          ++
Columns 3-9         Unused           _______
Columns 10-12       Sat #35 Accuracy __0
Columns 13-15       Sat #36 Accuracy __0
       *
       *
       *
Columns 58-60       Sat #51 Accuracy __0


SP3 Line Eleven

Columns 1-2         Symbols          ++
Columns 3-9         Unused           _______
Columns 10-12       Sat #52 Accuracy __0
Columns 13-15       Sat #53 Accuracy __0
       *
       *
       *
Columns 58-60       Sat #68 Accuracy __0


SP3 Line Twelve

Columns 1-2         Symbols          ++
Columns 3-9         Unused           _______
Columns 10-12       Sat #69 Accuracy __0
Columns 13-15       Sat #70 Accuracy __0
       *
       *
       *
Columns 58-60       Sat #85 Accuracy __0


SP3 Lines Thirteen and Fourteen

Columns 1-2         Symbols          %c
Column  3           Unused           _
Columns 4-5         2 characters     cc
Column  6           Unused           _
Columns 7-8         2 characters     cc
Column  9           Unused           _
Columns 10-12       3 characters     ccc
Column  13          Unused           _
Columns 14-16       3 characters     ccc
Column  17          Unused           _
Columns 18-21       4 characters     cccc
Column  22          Unused           _
Columns 23-26       4 characters     cccc
```

```
Column  27          Unused          _
Columns 28-31       4 characters    cccc
Column  32          Unused          _
Columns 33-36       4 characters    cccc
Column  37          Unused          _
Columns 38-42       5 characters    ccccc
Column  43          Unused          _
Columns 44-48       5 characters    ccccc
Column  49          Unused          _
Columns 50-54       5 characters    ccccc
Column  55          Unused          _
Columns 56-60       5 characters    ccccc


SP3 Lines Fifteen and Sixteen

Columns 1-2         Symbols         %f
Column  3           Unused          _
Columns 4-13        10-column float _0.0000000
Column  14          Unused          _
Columns 15-26       12-column float _0.000000000
Column  27          Unused          _
Columns 28-41       14-column float _0.00000000000
Column  42          Unused          _
Columns 43-60       18-column float _0.000000000000000


SP3 Lines Seventeen and Eighteen

Columns 1-2         Symbols         %i
Column  3           Unused          _
Columns 4-7         4-column int    ___0
Column  8           Unused          _
Columns 9-12        4-column int    ___0
Column  13          Unused          _
Columns 14-17       4-column int    ___0
Column  18          Unused          _
Columns 19-22       4-column int    ___0
Column  23          Unused          _
Columns 24-29       6-column int    _____0
Column  30          Unused          _
Columns 31-36       6-column int    _____0
Column  37          Unused          _
Columns 38-43       6-column int    _____0
Column  44          Unused          _
Columns 45-50       6-column int    _____0
Column  51          Unused          _
Columns 52-60       9-column int    ________0


SP3 Lines Nineteen to Twenty two

Columns 1-2         Symbols         /*
Column  3           Unused          _
Columns 4-60        Comment         CC...CC


SP3 Line Twenty three (The Epoch Header Record)

Columns 1-2         Symbols         *_
Column  3           Unused          _
Columns 4-7         Year Start      1994
Column  8           Unused          _
Columns 9-10        Month Start     12
Column  11          Unused          _
```

```
      Columns 12-13       Day of Month St  17
      Column  14          Unused           _
      Columns 15-16       Hour Start       _0
      Column  17          Unused           _
      Columns 18-19       Minute Start     _0
      Column  20          Unused           _
      Columns 21-31       Second Start     _0.00000000


      SP3 Line Twenty four (The Position and Clock Record)
      (See example 1)

      Column 1            Symbol           P
      Columns 2-4         Vehicle Id.      __1
      Columns 5-18        x-coordinate(km) __16258.524750
      Columns 19-32       y-coordinate(km) __-3529.015750
      Columns 33-46       z-coordinate(km) _-20611.427050
      Columns 47-60       clock (microsec) ____-62.540600
           *
           *
           *

  In addition, one could use the Velocity and Clock Rate-of-Change
  record, V, after the Position and Clock record.  The clock rate-
  of-change units are 10**-4 microseconds/second.

      SP3 Line Twenty five
      (See example 2)

      Column 1            Symbol           V
      Columns 2-4         Vehicle Id.      __1
      Columns 5-18        x-velocity(dm/s) __16258.524750
      Columns 19-32       y-velocity(dm/s) __-3529.015750
      Columns 33-46       z-velocity(dm/s) _-20611.427050
      Columns 47-60       clock rate-chg   ____-62.540600
           *
           *
           *


      SP3 Line 22+NUMEPS*(NUMSATS+1)+1 (i.e., The Last Line)

      Columns 1-3         Symbols          EOF

  !Discussion of the SP3 Format

       On line one, character two is the format version
  identification character.  The first released version has been
  designated version 'a'.  Subsequent versions will use lower case
  letters in alphabetical order.  The first line comprises the
  Gregorian date and time of day of the first epoch of the orbit,
  the number of epochs in the ephemeris file (up to 10 million),
  the data used descriptor, the orbit type descriptor, and the
  agency descriptor.  The data used descriptor was included for
  ease in distinguishing between multiple orbital solutions from a
  single organization.  This will have primary use for the agency
  generating the orbit.  A possible convention is given below; this
  is not considered final and suggestions are welcome.

      u   -- undifferenced carrier phase
      du  -- change in u with time
      s   -- 2-receiver/1-satellite carrier phase
      ds  -- change on s with time
      d   -- 2-receiver/2-satellite carrier phase
      dd  -- change in d with time
```

```
      U   -- undifferenced code phase
      dU  -- change in U with time
      S   -- 2-receiver/1-satellite code phase
      dS  -- change in S with time
      D   -- 2-receiver/2-satellite code phase
      dD  -- change in D with time
       +  -- type separator
```

Combinations such as "__u+U" seem reasonable. If the measurements used were complex combinations of standard types, then one could use "mixed" where mixed could be explained on the comment lines.

Orbit type is described by a three character descriptor. At this time only three have been defined: FIT (fitted), EXT (extrapolated or predicted), and BCT (broadcast). Naturally, others are possible. The computing agency descriptor allows four characters (e.g. _NGS).

The second line has: the GPS week (which will exceed 1000 in the year 1999); the seconds of the GPS Week elapsed at the start of the orbit (0.0 <= seconds of week < 604800.0); the epoch interval (0.0 < epoch interval < 100000.0) in seconds; the modified Julian Day Start (where 44244 represents GPS zero time -- January 6, 1980); and fractional part of the day (0.0 <= fractional < 1.0) at the start of the orbit.

The third line to the seventh lines indicate the number of satellites followed by their respective identifiers. The identifiers must use consecutive slots and continue on lines 4-7, if required. The value 0 should only appear after all the identifiers are listed. Satellite identifiers may be listed in any order. However, for ease in reviewing satellites included in the orbit file it is recommended that numerical order be used.

The eighth line to the twelfth lines have the orbit accuracy exponents. The value 0 is interpreted as accuracy unknown. A satellite's accuracy exponent appears in the same slot on lines 8-12 as the identifier on lines 3-7. The accuracy is computed from the exponent as in the following example. If the accuracy exponent is 13, the accuracy is 2**13 mm or 8 m. The quoted orbital error should represent one standard deviation and be based on the orbital error in the entire file for the respective satellite. This may lead to some distortion when orbit files are joined together.

Lines 13-18 allow the SP3 ASCII file to be modified, since the SP3 format has been designed so that additional parameters may be added.

Lines 19-22 are free form comments.

Line 23 is the epoch header date and time.

Line 24 is the position and clock line, and the first character is 'P' indicating a position line. The positional values are in kilometers and are precise to 1 mm. A precision of 0.5 mm can be accommodated if rounding is used, i.e., the value shown is never more than 0.5 mm from the computed value. The clock values are in microseconds and are precise to 1 picosecond. Bad or absent positional values are to be set to 0.000000. Bad or absent clock values are to be set to _999999.9999__. The six integer nines are required, whereas the fractional part nines are optional. When the position/velocity mode flag is set to 'V' in line one, each position record for a given satellite is followed

```
by a velocity record for the same satellite.  The first character
of the velocity record is a "V".  The velocity components are
given in decimeters/second and have a precision of 10**-4 mm/second.
The last column of a velocity record is the rate-of-change of
clock correction given in units of 10**-4 microsecond/second.  The
precision of this parameter is 10**-16 second/second.

!Example 1

#aP1994 12 17  0  0  0.00000000      96     d ITR92 FIT  NGS
##  779 518400.00000000   900.00000000 49703 0.0000000000000
+   25     1  2  4  5  6  7  9 12 14 15 16 17 18 19 20 21 22
+         23 24 25 26 27 28 29 31  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         7  6  5  5  5  5  5  5  5  6  5  5  5  5  6  5  5
++         5  5  6  5  5  5  5  5  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
%c cc cc ccc ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%c cc cc ccc ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%f  0.0000000  0.000000000  0.00000000000  0.000000000000000
%f  0.0000000  0.000000000  0.00000000000  0.000000000000000
%i    0    0    0    0      0      0      0      0         0
%i    0    0    0    0      0      0      0      0         0
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
*  1994 12 17  0  0  0.00000000
P  1  16258.524750  -3529.015750 -20611.427050    -62.540600
P  2 -21998.652100  -8922.093550 -12229.824050   -131.326200
P  4 -26019.547600   4809.810900  -2508.578200      3.544600
P  5   7014.950200  21130.960300 -14387.334650     79.692800
   *
   *
   *
P 28  13204.937750 -20485.533400  10794.787000     55.200800
P 29  -1638.431050 -24391.479200  10455.312650      3.690300
P 31   6265.255800 -25687.986950   -753.359000     70.830800
*  1994 12 17  0 15  0.00000000
P  1  15716.820135  -1169.850490 -21281.578766    -62.542746
P  2 -22813.261065  -9927.616864  -9816.490189   -131.328686
   *
   *
   *
P 28  13416.746195 -22186.753441   6248.864499     55.385492
P 29  -2745.269113 -22169.709690  14469.340453      3.718873
P 31   5629.986510 -25241.323751  -5659.769347     71.118497
*  1994 12 17 23 45  0.00000000
P  1  16708.907949  -5150.972262 -19904.291167    -62.727331
P  2 -21321.617042  -8048.187511 -13856.581227   -131.555527
P  4 -26107.382526   5010.736034   -422.963345      3.672587
P  5   7932.078481  21838.230749 -12767.671968     79.888744
   *
   *
   *
P 28  13308.321924 -21306.183480   8935.290694     55.387446
P 29  -2059.774801 -23532.083663  12229.852140      3.719337
P 31   6034.395625 -25605.621951  -2843.783172     71.121661
EOF!Example 2

#aV1994 12 17  0  0  0.00000000      96     d ITR92 FIT  NGS
```

```
##  779 518400.00000000   900.00000000 49703 0.0000000000000
+   25     1  2  4  5  6  7  9 12 14 15 16 17 18 19 20 21 22
+         23 24 25 26 27 28 29 31  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
+          0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         7  6  5  5  5  5  5  5  5  6  5  5  5  5  6  5  5
++         5  5  6  5  5  5  5  5  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
%c cc cc ccc ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%c cc cc ccc ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%f  0.0000000  0.000000000  0.00000000000  0.000000000000000
%f  0.0000000  0.000000000  0.00000000000  0.000000000000000
%i    0    0    0    0      0      0      0      0         0
%i    0    0    0    0      0      0      0      0         0
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
*  1994 12 17  0  0  0.00000000
P  1  16258.524750  -3529.015750 -20611.427050    -62.540600
V  1  -6560.373522  25605.954994  -9460.427179     -0.024236
P  2 -21998.652100  -8922.093550 -12229.824050   -131.326200
V  2  -9852.750736 -12435.176313  25738.634180     -0.029422
P  4 -26019.547600   4809.810900  -2508.578200      3.544600
V  4   2559.038002  -3340.527442 -31621.490838      0.016744
   *
   *
   *
P 29  -1638.431050 -24391.479200  10455.312650      3.690300
V 29   5754.005457 -12065.761570 -27707.056273      0.003537
P 31   6265.255800 -25687.986950   -753.359000     70.830800
V 31   3053.344058    -63.091750  31910.454757      0.033749
*  1994 12 17  0 15  0.00000000
P  1  15716.820135  -1169.850490 -21281.578766    -62.542746
V  1  -5439.955846  26738.341429  -5409.793390     -0.023226
P  2 -22813.261065  -9927.616864  -9816.490189   -131.328686
V  2  -8178.974330  -9924.329320  27813.754308     -0.025238
   *
   *
   *
P 31   5629.986510 -25241.323751  -5659.769347     71.118497
V 31   5213.646243  -5585.922919  30831.379942      0.040199
*  1994 12 17 23 45  0.00000000
P  1  16708.907949  -5150.972262 -19904.291167    -62.727331
V  1  -7218.304166  24494.550676 -12283.334526     -0.023824
   *
   *
   *
P 31   6034.395625 -25605.621951  -2843.783172     71.121661
V 31   3831.346050  -2469.229615  31655.436179      0.028935
EOF!                          REFERENCES


1.  Remondi, B. W. 1985: Distribution of Global Positioning
System Ephemerides by the National Geodetic Survey, Presented at
the First Conference on Civil Applications of GPS - Institute of
Navigation, September 12, 1985, 8 pp.

2.  Remondi, B. W. 1989: Extending the National Geodetic Survey
Geodetic Orbit Formats, NOAA Technical Report 133 NGS 46, 85 pp.

3.  Remondi, B. W., 1991: NGS Second Generation ASCII and Binary
```

Orbit Formats and Associated Interpolated Studies, Proceedings of the Twentieth General Assembly, International Union of Geodesy and Geophysics, Vienna, Austria, August 11-24, 1991, 28 pp.

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