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
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
/* CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
*  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
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