The GPS Receiver

- A Commonly Overlooked Test Tool

Jim Baker

NDIA 29th Annual
National T&E Conference
July 22, 2014

http://www.cafepress.com

Agenda

- Objective
- History/National Policy
- GPS
- NMEA
- Applications in T&E
- Summary
- References

Objective

To educate engineers and other technical readers on the breadth and depth of data available from modern GPS devices which are often overlooked during test planning and data analysis.

Applications in T&E

- Data useful for Lab and Mobile Test events
- Provides additional factors for consideration in DOE
- Simple data format lends itself to automated testing, analysis, and reporting
- May just provide that missing link for explaining anomalies

History/National Policy

1973 – Development began on a satellite navigation system for DoD

1983 -- Flight KAL 007 was shot down after straying into Soviet airspace, President Reagan declares that GPS would be made available to the general public after it became operational to help prevent such tragedies in the future

1989 – the first GPS satellite is launched

1994 – GPS becomes fully operational with 24 satellites

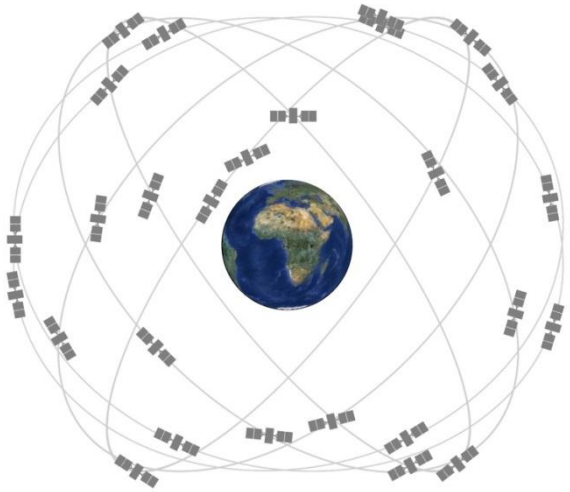
1996 – President Clinton establishes comprehensive national policy on joint civil/military GPS management

2000 – Selective Availability mode is turned off, providing civilians with significant increase in accuracy (from ~100 meters to ~12 meters)

2010 – First Block IIF satellite launched, adds third frequency for use in civilian transportation safety

GPS Technical Overview

Three Segments

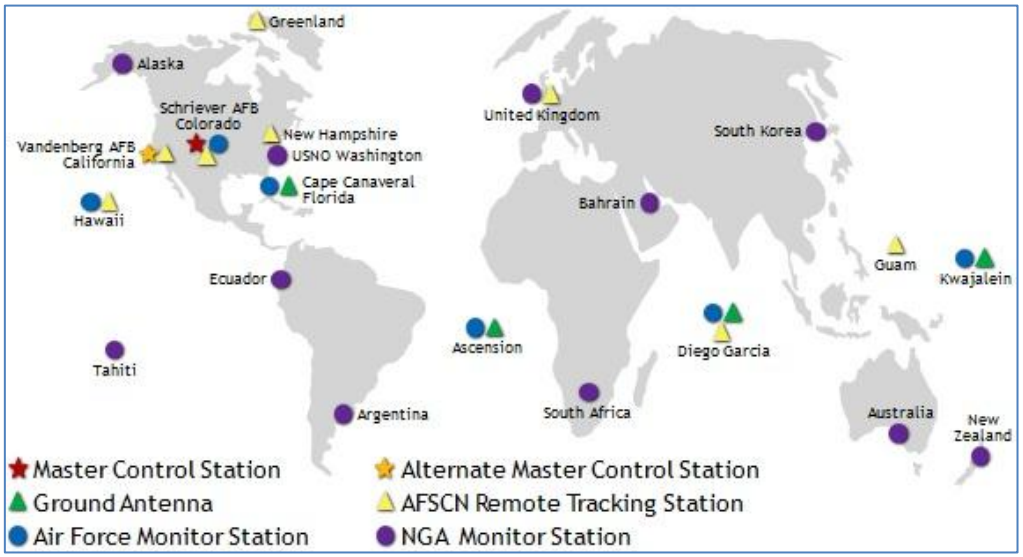


Space Segment

– 24-32 satellites at 20,200 km

User Segment

– GPS receivers



Control Segment

– Control and tracking stations monitor satellites, transmit data and program uploads, record telemetry, resolve anomalies

GPS Receivers

- Numerous vendors to choose from
- Available in wide range of shapes and sizes
- Wide variety of functionality and capability
- Most provide serial output for NMEA messages
- TIA-232/422 serial interfaces

NMEA

- National Marine Electronics Association (NMEA) maintains the electrical and message specifications for communication between marine electronic devices, including GPS

- The NMEA 0183 Interface Standard:
  - Defines the electrical signal requirements, data transmission protocol, and specific sentence formats for a serial data bus
  - This standard supports one-way serial data transmission from a single talker (e.g. GPS receiver) to one or more listeners (e.g. computers)

- The NMEA 0183 standard is not available through open/public sources, is available for purchase at http://www.nmea.org

Some Standard Messages

$GPBWC Bearing and Distance to Waypoint

$GPDTM Datum Reference

$GPGGA Time, position and fix related data for a GPS receiver

$GPGLL Geographic position and related data

$GPGSA Dilution of Precision (DoP) and active satellite info

$GPGSV Satellites in view

$GPRMC Recommended Minimum Navigation Information “C”

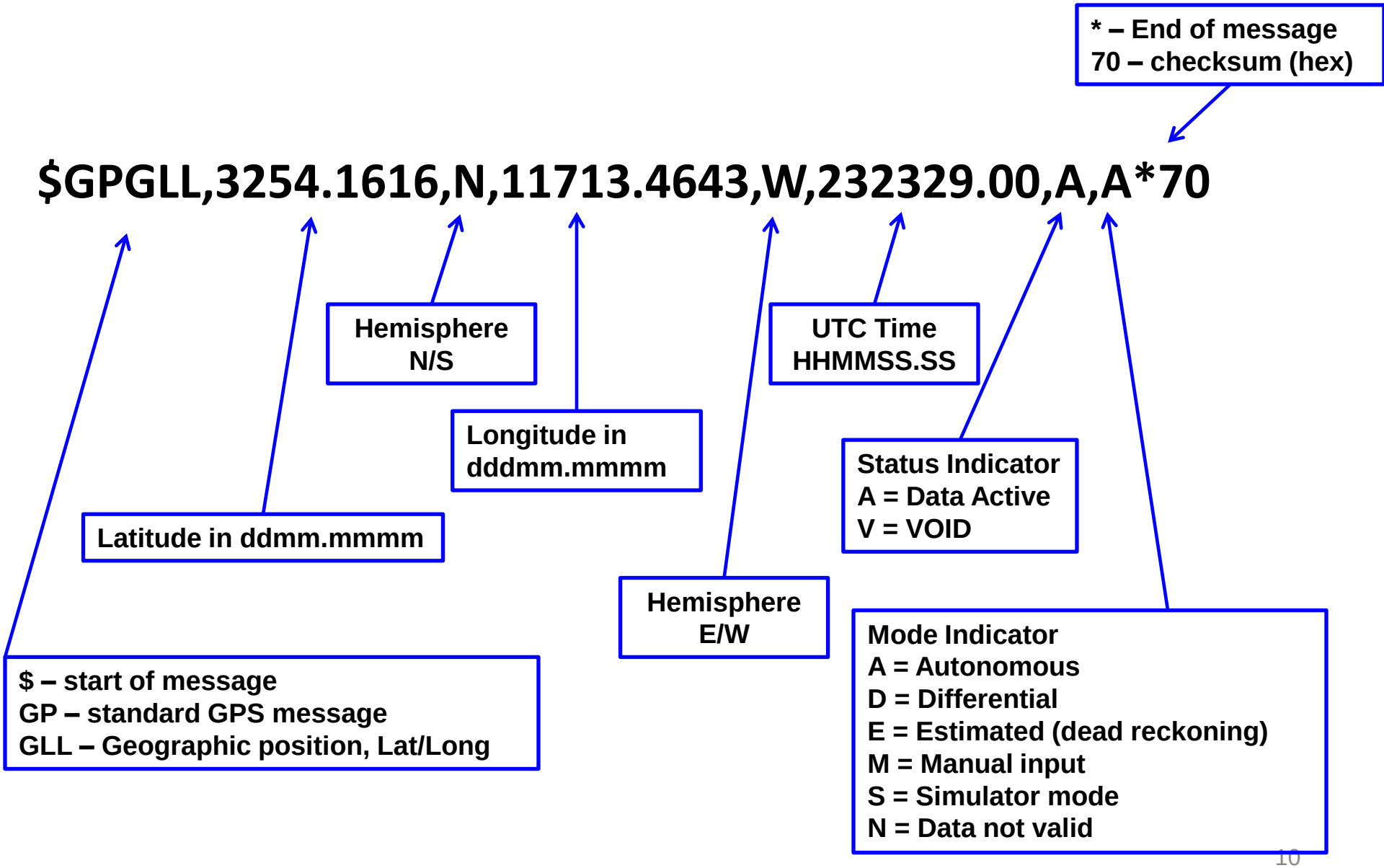
$GPRTE Route info

$GPVTG Vector track and speed over the ground

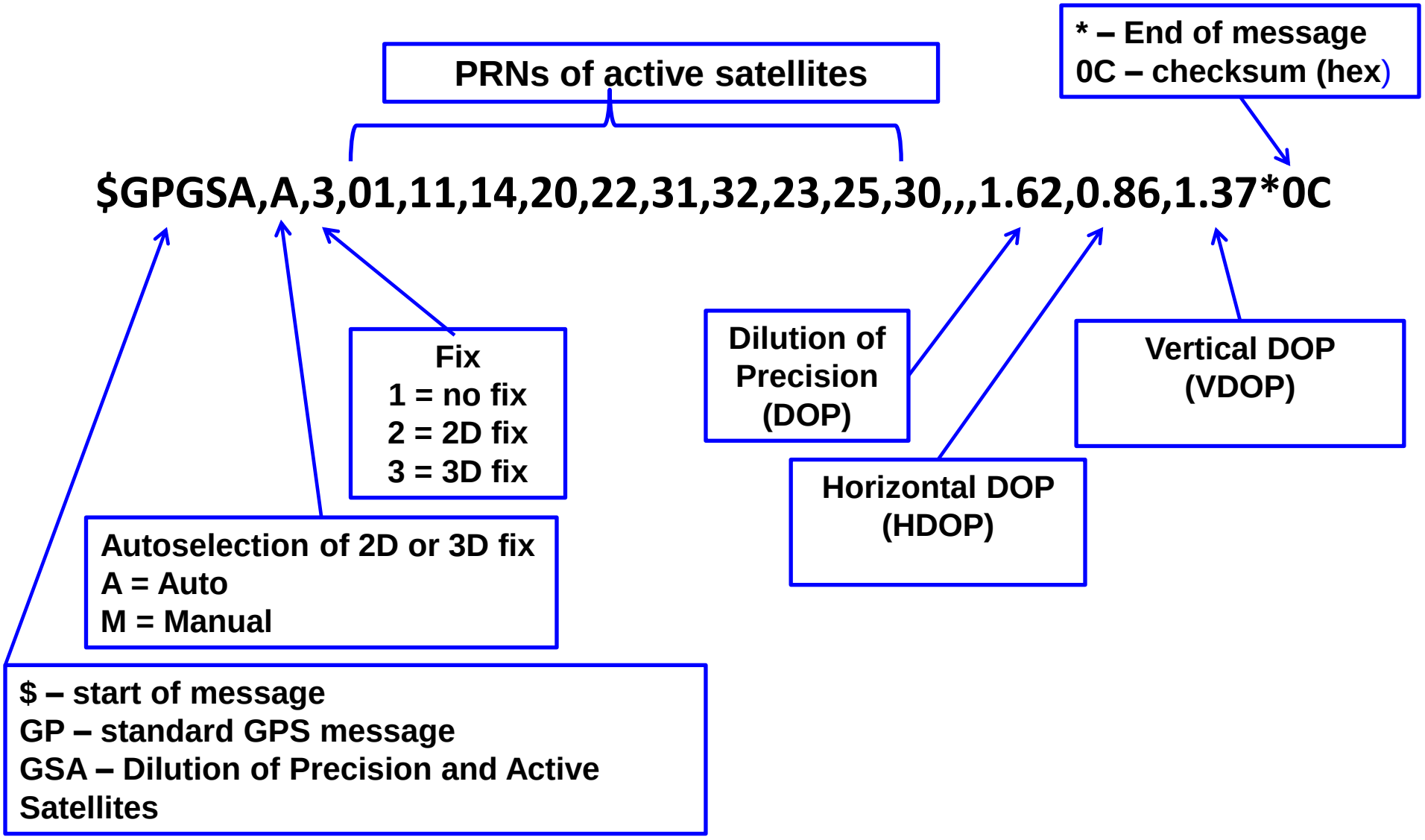
$GPWCV Waypoint closure velocity (velocity made good)

$GPWNC Distance, waypoint to waypoint

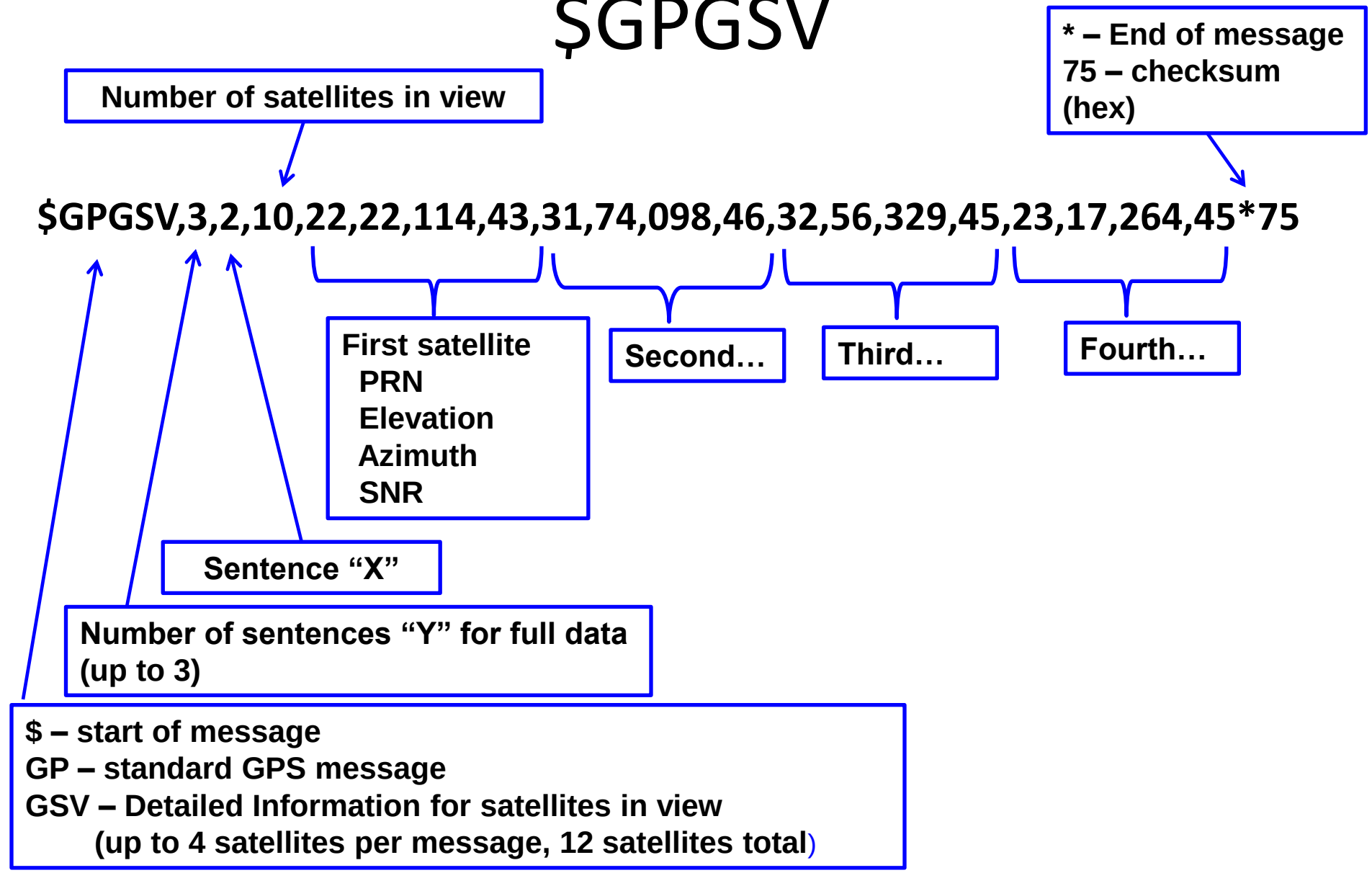
$GPGLL


* – End of message
70 – checksum (hex)
$GPGLL,3254.1616,N,11713.4643,W,232329.00,A,A*70
Hemisphere
N/S
UTC Time
HHMMSS.SS
Longitude in
dddmm.mmmm
Status Indicator
A = Data Active
V = VOID
Latitude in ddmm.mmmm
Hemisphere
E/W
Mode Indicator
A = Autonomous
D = Differential
E = Estimated (dead reckoning)
M = Manual input
S = Simulator mode
N = Data not valid
$ – start of message
GP – standard GPS message
GLL – Geographic position, Lat/Long

$GPGSA


PRNs of active satellites
* – End of message
0C – checksum (hex)
$GPGSA,A,3,01,11,14,20,22,31,32,23,25,30,,,1.62,0.86,1.37*0C
Fix
1 = no fix
2 = 2D fix
3 = 3D fix
Dilution of Precision (DOP)
Vertical DOP (VDOP)
Horizontal DOP (HDOP)
Autoselection of 2D or 3D fix
A = Auto
M = Manual
$ – start of message
GP – standard GPS message
GSA – Dilution of Precision and Active Satellites

$GPGSV


Number of satellites in view
* – End of message
75 – checksum
(hex)
$GPGSV,3,2,10,22,22,114,43,31,74,098,46,32,56,329,45,23,17,264,45*75
First satellite
PRN
Elevation
Azimuth
SNR
Second…
Third…
Fourth…
Sentence “X”
Number of sentences “Y” for full data
(up to 3)
$ – start of message
GP – standard GPS message
GSV – Detailed Information for satellites in view
(up to 4 satellites per message, 12 satellites total)

Partial Listing of Available Data

- Position (Latitude, Longitude, Elevation)
- Bearing and Velocity
- Steering and Time to next waypoint*
- Route Information, Cross-Track Error*
- Number of satellites in view
- PRN, Azimuth, Elevation, and S/N of all satellites in view
- PRNs of active satellites (used in navigation solution)
- Dilution of Precision (DOP) (indicator for error due to satellite geometry)
- Figure of Merit* (another indicator for error, includes DOP, atmospherics, S/N, and other factors)
- Estimated Position Error* (horizontal, vertical, and spherical)
- Type of fix (2D or 3D)
- Differential* GPS status and information
- Geoidal Separation (distance between WGS-84 datum and Mean Sea Level)
- UTC Date and Time (Local Time*), GPS Week # and Seconds
- Leap Seconds (correction between GPS and UTC time)

* varies with receivers, some use proprietary messages

Applications in T&E

- Lab testing
  - Provide common time reference for automated test and data recording systems (cheap workaround if NTP is not available)
  - Emulate mobile events by playing back NMEA messages
- Mobile testing
  - Record receiver data (e.g., time, position, velocity, track) every second
  - Provide common time reference for distributed mobile systems
  - Simply route reconstruction

- Record or Playback raw NMEA messages at serial port
- Simple data format lends itself to automated testing, analysis, and reporting

Notional Mobile Test Event

- **Worst Case**– no GPS, operator marks position/data on a map
- **Slightly Better Case** – operator uses GPS for navigation but doesn't record anything (think about slide #2)
- **Better Case** – operator uses GPS, manually copies information from GPS at selected waypoints
  - Testers using this method typically only record minimum data
  - Different testers may apply different levels of rigor to recording time
- **Best Case** – operator uses GPS, connects serial port to laptop and records selected NMEA messages from start to finish of the test route
  - Huge amount of additional data available for analysis for minimal effort
  - NMEA data can be exported directly to numerous mapping tools
  - NMEA data can be archived with rest of the test artifacts
  - Now have additional variables for use in DOE

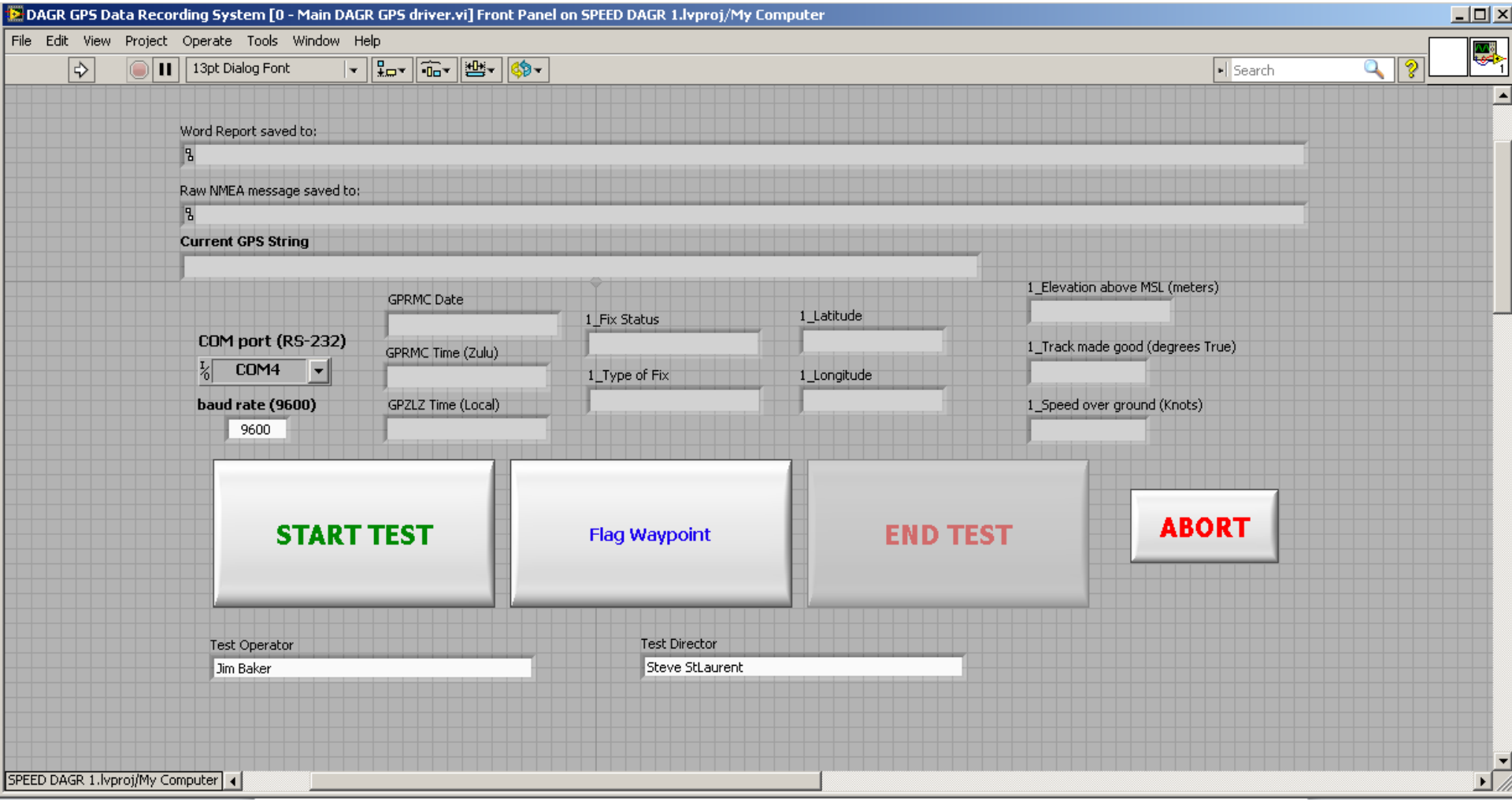
Test Tool Applications

- **HYPERTERM (terminal emulator)**
  - Display raw data stream
  - Record to text
- **LabVIEW (application development software)**
  - Display raw data stream
  - Record to text
  - Perform near-real-time analysis
  - Generate automated reports
  - Advanced tools available for post-analysis
  - Playback re-recorded NMEA file to multiple serial ports

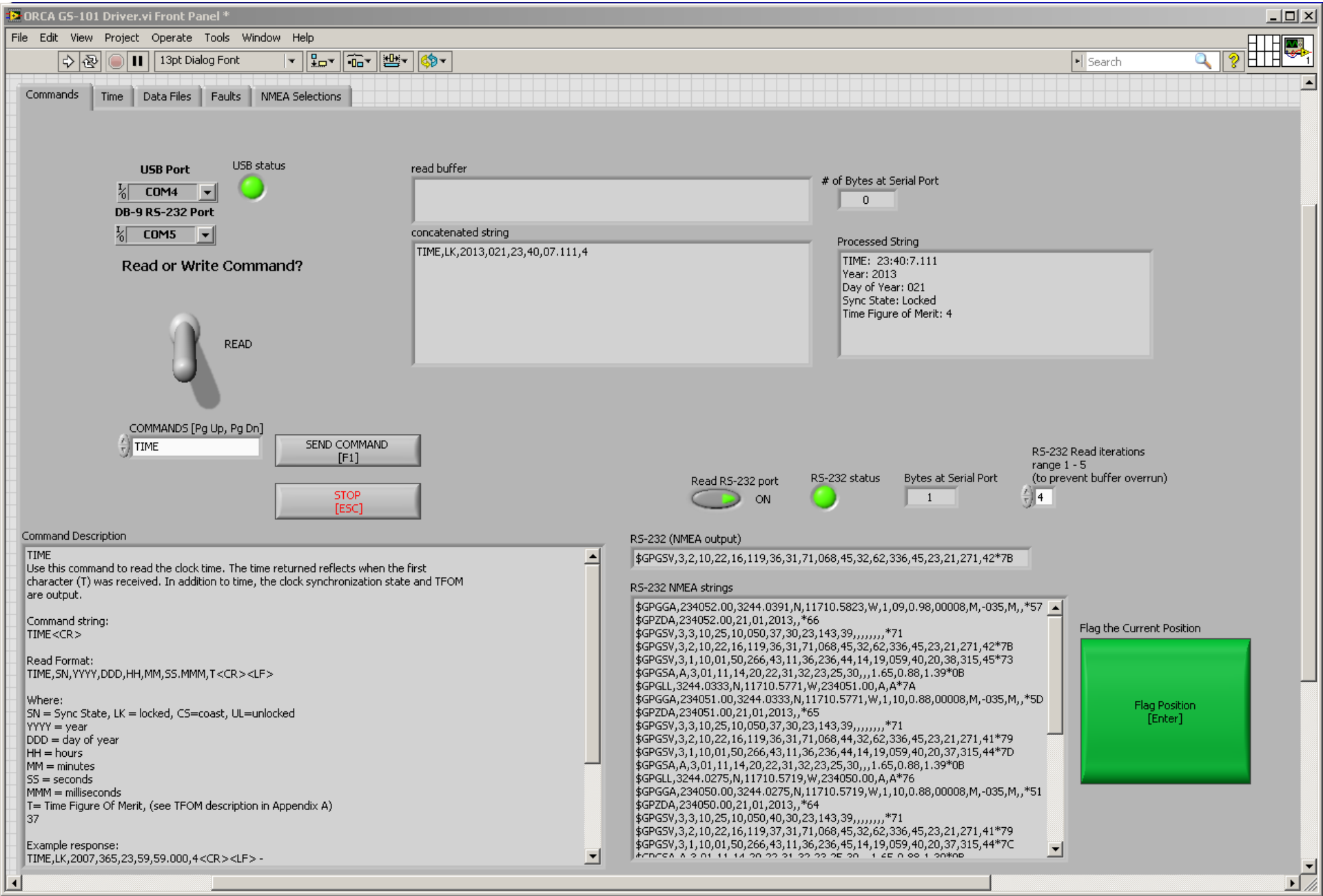
Hyperterminal - http://www.hilgraeve.com/hyperterminal/

LabVIEW - http://www.ni.com/labview/

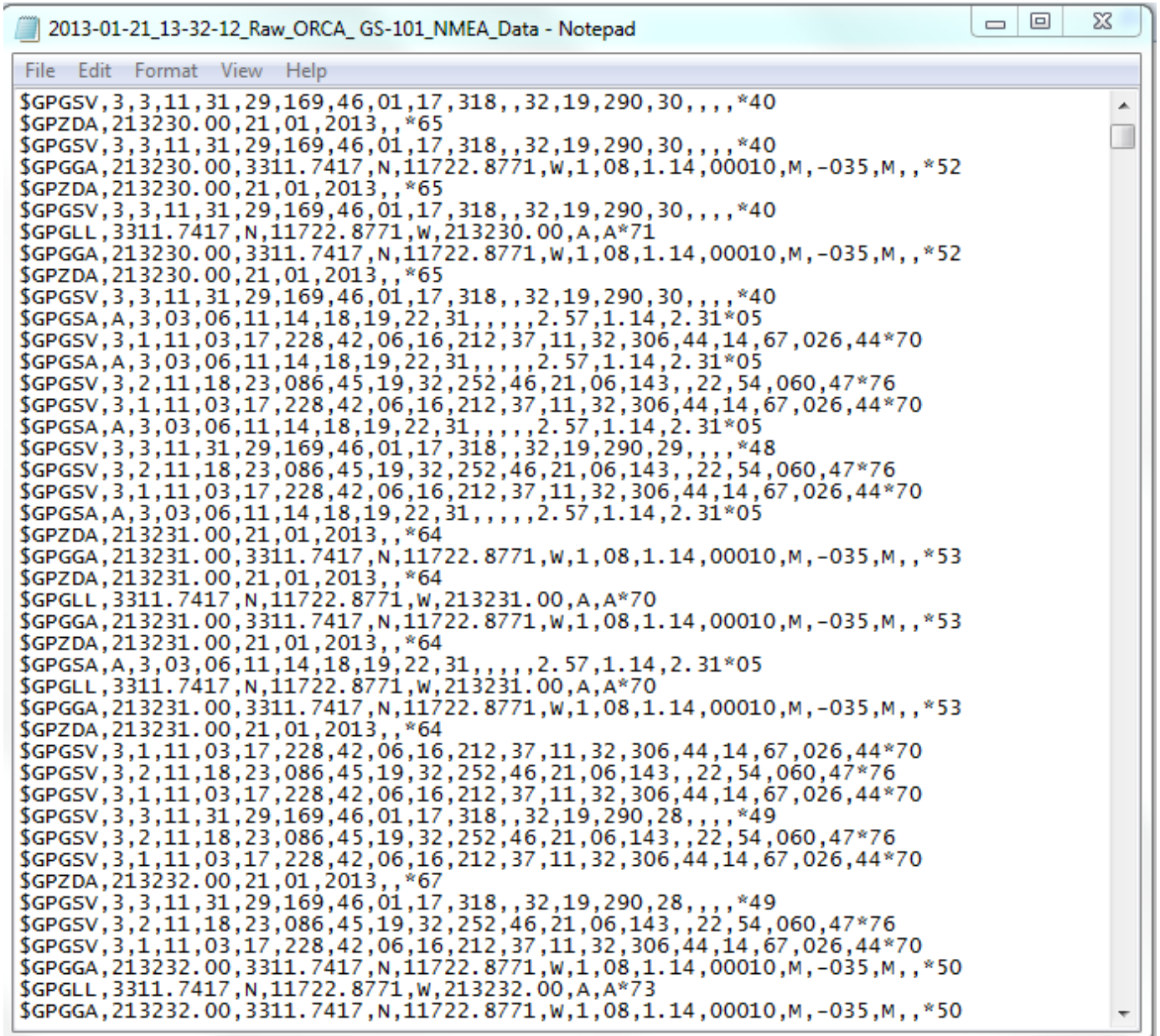
LabVIEW Application for DAGR



LabVIEW Application for ORCA



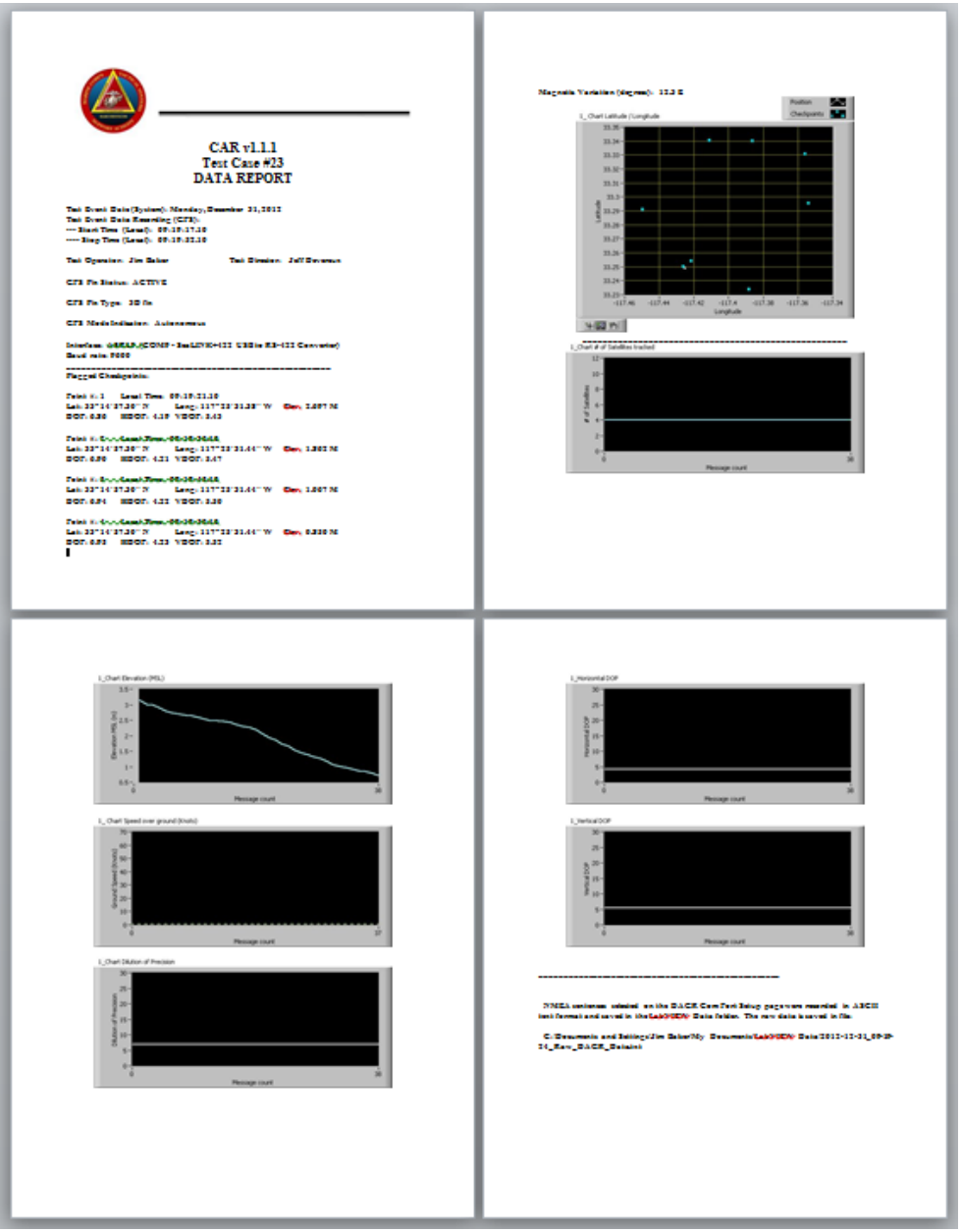
Sample of Raw Data


2013-01-21_13-32-12_Raw_ORCA_ GS-101_NMEA_Data - Notepad

File Edit Format View Help

```
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,30,,,,*40
$GPZDA,213230.00,21,01,2013,,*65
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,30,,,,*40
$GPGGA,213230.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*52
$GPZDA,213230.00,21,01,2013,,*65
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,30,,,,*40
$GPGLL,3311.7417,N,11722.8771,W,213230.00,A,A*71
$GPGGA,213230.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*52
$GPZDA,213230.00,21,01,2013,,*65
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,30,,,,*40
$GPGSA,A,3,03,06,11,14,18,19,22,31,,,,,2.57,1.14,2.31*05
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGSA,A,3,03,06,11,14,18,19,22,31,,,,,2.57,1.14,2.31*05
$GPGSV,3,2,11,18,23,086,45,19,32,252,46,21,06,143,,22,54,060,47*76
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGSA,A,3,03,06,11,14,18,19,22,31,,,,,2.57,1.14,2.31*05
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,29,,,,*48
$GPGSV,3,2,11,18,23,086,45,19,32,252,46,21,06,143,,22,54,060,47*76
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGSA,A,3,03,06,11,14,18,19,22,31,,,,,2.57,1.14,2.31*05
$GPZDA,213231.00,21,01,2013,,*64
$GPGGA,213231.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*53
$GPZDA,213231.00,21,01,2013,,*64
$GPGLL,3311.7417,N,11722.8771,W,213231.00,A,A*70
$GPGGA,213231.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*53
$GPZDA,213231.00,21,01,2013,,*64
$GPGSA,A,3,03,06,11,14,18,19,22,31,,,,,2.57,1.14,2.31*05
$GPGLL,3311.7417,N,11722.8771,W,213231.00,A,A*70
$GPGGA,213231.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*53
$GPZDA,213231.00,21,01,2013,,*64
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGSV,3,2,11,18,23,086,45,19,32,252,46,21,06,143,,22,54,060,47*76
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,28,,,,*49
$GPGSV,3,2,11,18,23,086,45,19,32,252,46,21,06,143,,22,54,060,47*76
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPZDA,213232.00,21,01,2013,,*67
$GPGSV,3,3,11,31,29,169,46,01,17,318,,32,19,290,28,,,,*49
$GPGSV,3,2,11,18,23,086,45,19,32,252,46,21,06,143,,22,54,060,47*76
$GPGSV,3,1,11,03,17,228,42,06,16,212,37,11,32,306,44,14,67,026,44*70
$GPGGA,213232.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*50
$GPGLL,3311.7417,N,11722.8771,W,213232.00,A,A*73
$GPGGA,213232.00,3311.7417,N,11722.8771,W,1,08,1.14,00010,M,-035,M,,*50
```

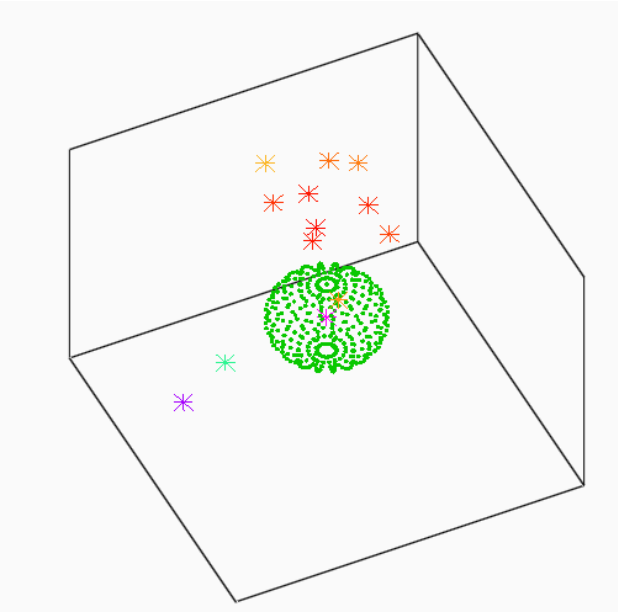
Automated Test Report

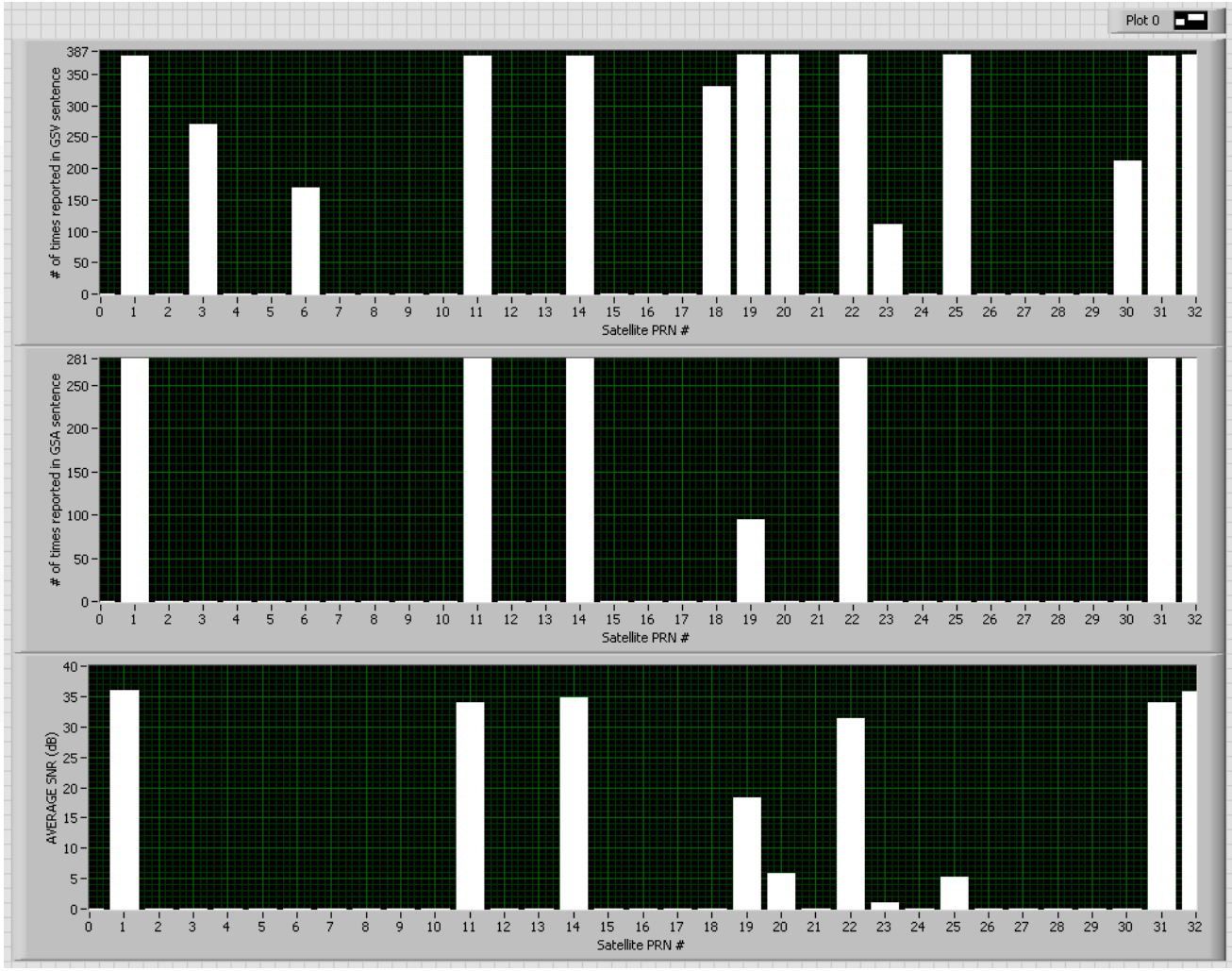


CAR v1.1.1
Test Case #23
DATA REPORT

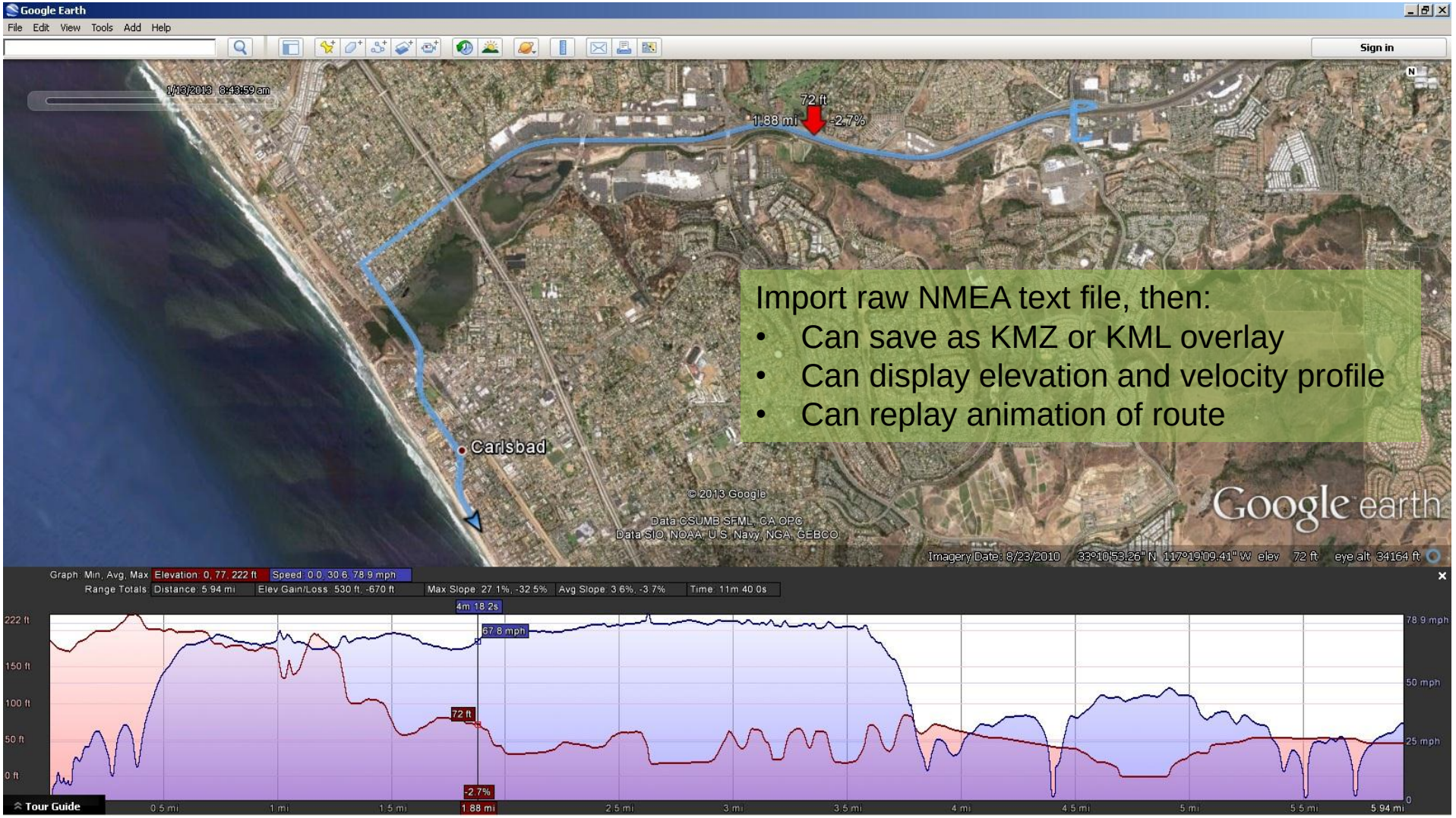
- Fully automated test report
- Report created after operator hits “stop” button

Examples of Post Analysis



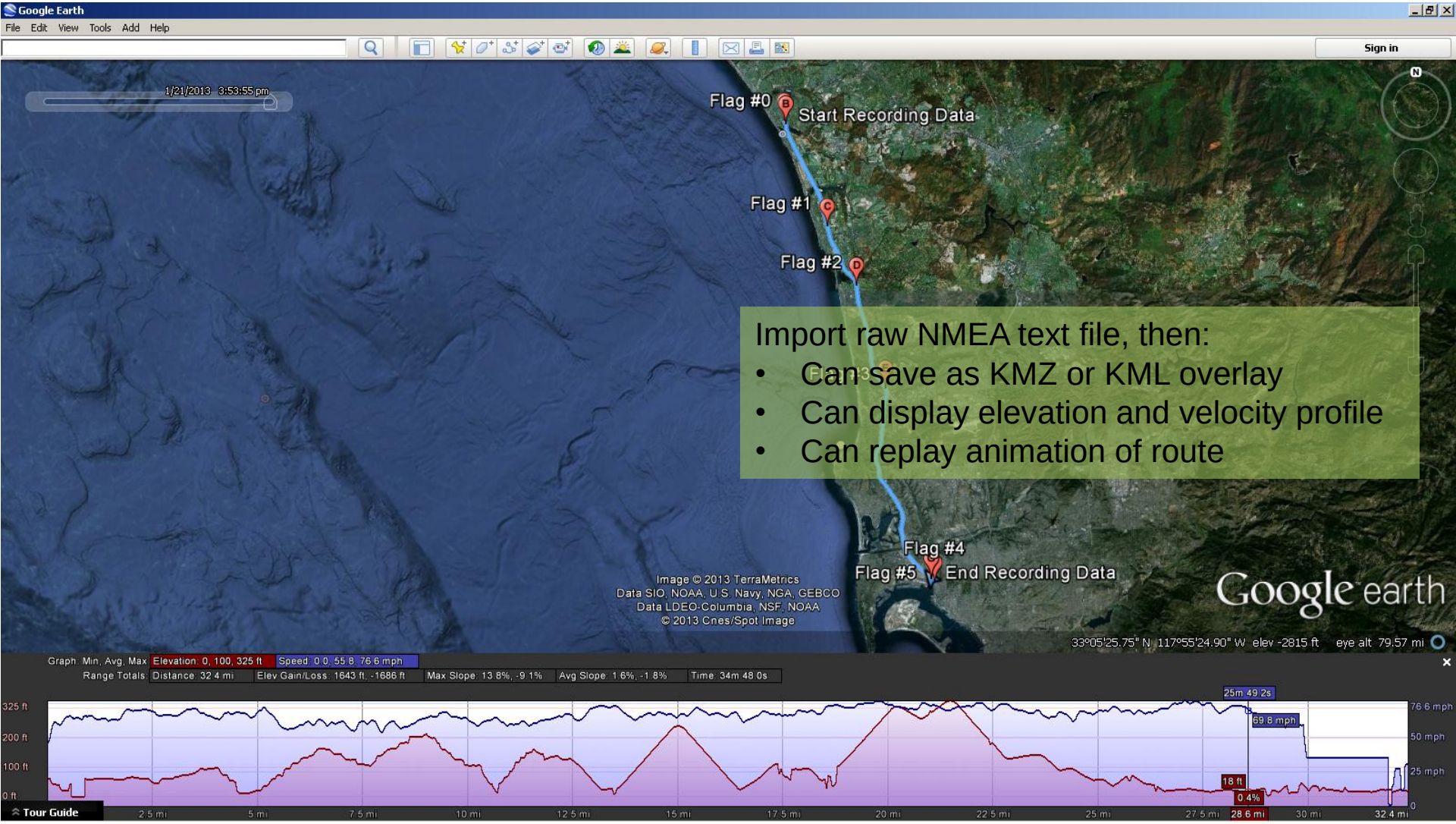


Google Earth



http://www.google.com/earth/index.html

Google Earth w/waypoints



http://www.google.com/earth/index.html

Summary

- **GPS Receivers**
  - support a common set of general GPS messages in NMEA format
  - continuously write NMEA messages out, usually via a serial interface
  - rely on precision time, can be used to synchronize test equipment
- **NMEA Messages**
  - update once a second in typical GPS receivers
  - can be recorded in ASCII text file by almost any application that can read the serial port
  - Provide estimates of error and indicators for precision
- Various commercial GPS receivers provide additional proprietary messages in addition to the standard NMEA messages
- **A GPS receiver can be an invaluable tool for any test activity**

Online Resources

- www.gps.gov – Official U.S. Government information about the Global Positioning System (GPS) and related topics
- http://www.usno.navy.mil/USNO/time/gps -- U.S. Naval Observatory, GPS Data and Information
- http://www.gps.gov/cgsic/ -- Civil GPS Service Interface Committee
- http://www.navcen.uscg.gov – U.S. Coast Guard Navigation Center
- www.nmea.org – National Marine Electronics Association

Contact Info

Jim Baker

Test & Certification Group (T&CG)

Marine Corps Tactical Systems Support Activity (MCTSSA)

BOX 555171

Camp Pendleton, CA 92055-5171

Work: (760) 725-2960

Email: james.m.baker1@usmc.mil

Backup Slides

NMEA 2000

- NMEA 0183 is slowly being replaced by NMEA 2000

- NMEA 2000 is primarily geared for networking electronic devices and marine instruments on boats
  - Compact binary message format vice ASCII
  - many-to-many talkers vice one-to-many
  - Controller Area Network (CAN) vice serial

Leap Second

- Universal Coordinated Time (referred to as UTC) The UTC broadcast from GPS is referenced to the U. S. Naval Observatory real-time realization of UTC called UTC(USNO).
  - UTC(USNO) is obtained from GPS by subtracting an integral number of seconds (leap seconds) and applying the fine UTC correction information contained in the broadcast navigation data.

- Global Positioning System (GPS) Time
  - Internal navigation time scale computed from the ensemble of clocks that make up the GPS system and is steered closely to UTC(USNO) modulo one second.
  - GPS Time, is not adjusted for leap seconds and is not intended to be used for timing applications. GPS time repeats ever 19.6 years, Epoch #1 started counting whole seconds on Jan 6, 1980. GPS time Epoch #2 started on Aug 22, 1999 and Epoch #3 will start in 2019.
- Leap Second is currently +16 and was last updated June 30, 2012.

Garmin Leap Second Rollover
June 30, 2012

$PGRMF,671,13,300612,235958,15,3314.9898,N,11725.4705,W,A,2,0,123,2,1*08

$PGRMF,671,14,300612,235959,15,3314.9898,N,11725.4705,W,A,2,0,123,2,1*0E

$PGRMF,671,15,300612,235959,16,3314.9899,N,11725.4705,W,A,2,0,123,2,1*0D

$PGRMF,671,16,010712,000000,16,3314.9900,N,11725.4704,W,A,2,0,123,2,1*0C

$PGRMF,671,17,010712,000001,16,3314.9902,N,11725.4704,W,A,2,0,123,2,1*0E

$PGRMF,671,18,010712,000002,16,3314.9908,N,11725.4702,W,A,2,1,126,2,1*0A

$PGRMF,671,19,010712,000003,16,3314.9919,N,11725.4706,W,A,2,2,126,2,1*0D

$PGRMF,671,20,010712,000004,16,3314.9931,N,11725.4708,W,A,2,2,8,2,1*09

$PGRMF,671,21,010712,000005,16,3314.9937,N,11725.4707,W,A,2,2,6,2,1*0E

ORCA Leap Second Rollover
June 30, 2012

$GPZDA,235959.00,30,06,2012,00,00*63

$GPZDA,235960.00,30,06,2012,00,00*69

$GPZDA,000000.00,30,07,2012,00,00*63

$GPZDA,000001.00,30,07,2012,00,00*62

$GPZDA,000002.00,30,07,2012,00,00*61

$GPZDA,000003.00,30,07,2012,00,00*60

$GPZDA,000004.00,01,07,2012,00,00*65

$GPZDA,000005.00,01,07,2012,00,00*64

$GPZDA,000006.00,01,07,2012,00,00*67