



Augmenting Data Exchange Formats for OPUS of the Future

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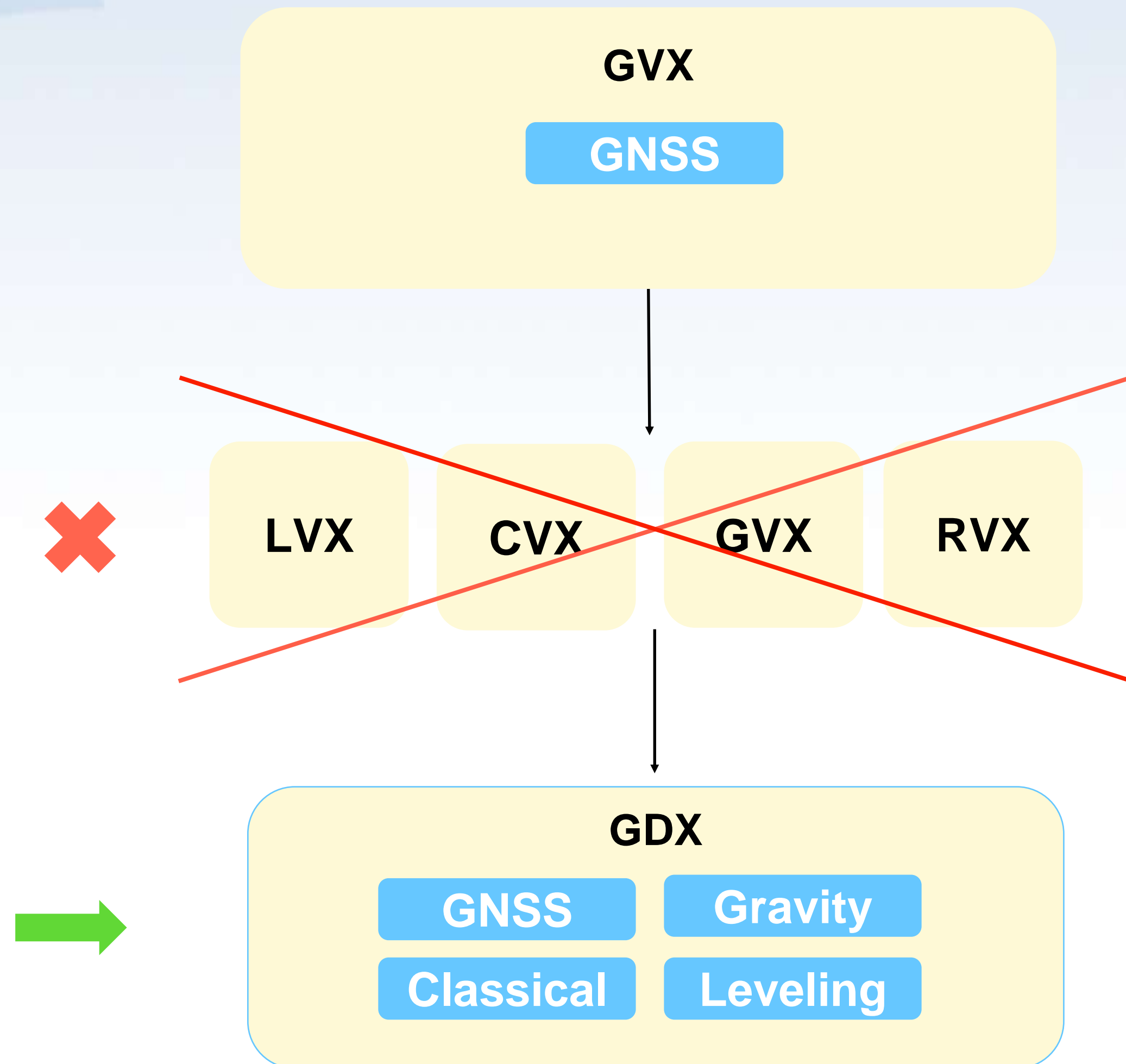
Presented May 31, 2023

FIG Working Week



Geodetic Data Exchange (GD~~X~~)

- GD~~X~~ is an XML-based data format that will be the input format for OPUS
- GD~~X~~ will be the successor to the GNSS Vector Exchange (GVX) format and is designed to be backwards-compatible with Bluebook
- GD~~X~~ currently supports GNSS, classical, and leveling measurements



GDX Structure

1 . SOURCE_DATA

2 . PROJECT_INFORMATION

3 . PERSONNEL

4 . UNITS

5 . EQUIPMENT

6 . POINTS

7 . MEASUREMENT_SETTINGS

8 . MEASUREMENTS

9 . REDUCTIONS

10 . OBSERVATIONS

Source Data

1.1. SOURCE_DATA

1.1.1. FILE_NAME

1.1.2. CREATED_DATE

1.1.3. SOURCE_APPLICATION

1.1.3.1. NAME

1.1.3.2. VERSION

1.1.3.3. MANUFACTURER

1.1.3.4. MANUFACTURER_URL

1.1.4. CONVERTED_BY

1.1.4.1. SOFTWARE_NAME

1.1.4.2. VERSION

1.1.4.3. SOFTWARE_URL

1.1.4.4. CONVERTED_DATE

```
<SOURCE_DATA>
<FILE_NAME>wash_mon_20150128</FILE_NAME>
<CREATED_DATE>2013-11-05T06:46:05</CREATED_DATE>
<SOURCE_APPLICATION>
<NAME>GeoObs</NAME>
<VERSION>1.40</VERSION>
<MANUFACTURER />
<MANUFACTURER_URL />
</SOURCE_APPLICATION>
<CONVERTED_BY>
<SOFTWARE_NAME>Trav to cvx xml</SOFTWARE_NAME>
<VERSION>1</VERSION>
<SOFTWARE_URL />
<CONVERTED_DATE>2021-08-17T13:42:02</CONVERTED_DATE>
</CONVERTED_BY>
</SOURCE_DATA>
```

Project Information

- 1.2. PROJECT_INFORMATION
 - 1.2.1. TITLE
 - 1.2.2. SUBTITLE_1
 - 1.2.3. SUBTITLE_2
 - 1.2.4. SUBTITLE_3
 - 1.2.5. NGS_SURVEY_PROJECT_ID
 - 1.2.6. AGENCY
 - 1.2.7. START_DATE
 - 1.2.8. END_DATE
 - 1.2.9. REMARK

```
<PROJECT_INFORMATION>
<TITLE>WASHINGTON MONUMENT</TITLE>
<SUBTITLE_1 />
<SUBTITLE_2 />
<SUBTITLE_3 />
<NGS_SURVEY_PROJECT_ID />
<AGENCY>National Geodetic Survey</AGENCY>
<START_DATE>2013-11-05T11:44:10</START_DATE>
<END_DATE>2013-11-06T14:16:54</END_DATE>
<REMARK />
</PROJECT_INFORMATION>
```

Personnel

1.3. PERSONNEL

1.3.1. PARTY_CHIEF

1.3.2. INITIALS

```
<PERSONNEL>  
  <PARTY_CHIEF INITIALS = "KLF">Kendall Fancher</PARTY_CHIEF>  
  <NAME INITIALS = "SEB">Steve Breidenbach</NAME>  
  <NAME INITIALS = "CG">Charles Geoghegan</NAME>  
</PERSONNEL>
```

Coordinate Reference Systems

1.4. COORDINATE_REFERENCE_SYSTEMS

1.4.1. GEODETIC_CRIS

1.4.1.1. ID

1.4.1.2. CODE

1.4.1.3. NAME

1.4.1.4. REMARK

1.4.2. VERTICAL_CRIS

1.4.2.1. ID

1.4.2.2. CODE

1.4.2.3. NAME

1.4.2.4. REMARK

```
<COORDINATE_REFERENCE_SYSTEMS>
  <GEODETIC_CRIS>
    <ID>239</ID>
    <CODE />
    <NAME>NAD 83 (2011) Epoch 2010 - LatLonEht</NAME>
    <REMARK />
  </GEODETIC_CRIS>
  <GEODETIC_CRIS>
    <ID>252</ID>
    <CODE />
    <NAME>NAD 83 (2011) Epoch 2010 - XYZ</NAME>
    <REMARK />
  </GEODETIC_CRIS>
  <VERTICAL_CRIS>
    <ID>256</ID>
    <CODE />
    <NAME>NAVD88 - Oht</NAME>
    <REMARK />
  </VERTICAL_CRIS>
</COORDINATE_REFERENCE_SYSTEMS>
```


Equipment

- Schema is a bit too detailed to show, but a snippet is shown here
- Support for
 - GNSS Antennas
 - Levels
 - Rods
 - Total stations
 - Targets
- Will add support for measurement tapes, historical EDM equipment, and other instrument types

```
<EQUIPMENT>
  <LEVEL>
    <ID>LI1</ID>
    <NGS_EQUIPMENT_CODE>243</NGS_EQUIPMENT_CODE>
    <MANUFACTURER>Leica</MANUFACTURER>
    <MODEL>DNA03</MODEL>
    <SERIAL_NUMBER>332228</SERIAL_NUMBER>
    <FIRMWARE_VERSION>0</FIRMWARE_VERSION>
    <STADIA_FACTOR_CODE="full">200</STADIA_FACTOR>
  </LEVEL>
  <ROD>
<ID>R001</ID>
<NGS_EQUIPMENT_CODE>396</NGS_EQUIPMENT_CODE>
  <MANUFACTURER>Leica</MANUFACTURER>
  <MODEL>GPCL2</MODEL>
  <TYPE>Bar-code</TYPE>
  <MATERIAL>Invar</MATERIAL>
<SERIAL_NUMBER>26685</SERIAL_NUMBER>
<ROD_CONSTANT></ROD_CONSTANT>
<ROD_UNITS>centimeters</ROD_UNITS>
```

Points

```

1.7. POINTS
  1.7.1. POINT
    1.7.1.1. ID
    1.7.1.2. NAME
    1.7.1.3. NGS_EQUIPMENT_CODE
    1.7.1.4. NGS_PID
    1.7.1.5. DESIGNATION
    1.7.1.6. COORDINATES
      1.7.1.6.1. GEODETIC_COORDINATES
      1.7.1.6.2. GEODETIC_CRN_ID
      1.7.1.6.3. COORDINATE_REFERENCE_SYSTEM_ID
      1.7.1.6.4. EPOCH
      1.7.1.6.5. LATITUDE
      1.7.1.6.6. LONGITUDE
      1.7.1.6.7. ELLIPSOIDAL_HEIGHT
      1.7.1.6.8. GLOBAL_CARTESIAN_COORDINATES
        1.7.1.6.8.1. GEODETIC_CRN_ID
        1.7.1.6.8.2. EPOCH
        1.7.1.6.8.3. X
        1.7.1.6.8.4. Y
        1.7.1.6.8.5. Z
      1.7.1.6.9. CORRELATION_MATRIX_LOCAL
        1.7.1.6.9.1. SDN
        1.7.1.6.9.2. SDE
        1.7.1.6.9.3. SDU
        1.7.1.6.9.4. PNE
        1.7.1.6.9.5. PNU
        1.7.1.6.9.6. PEU
    1.7.1.7. ORTHOMETRIC_HEIGHT
      1.7.1.7.1. VERTICAL_CRN_ID
      1.7.1.7.2. EPOCH
      1.7.1.7.3. VERTICAL_COORDINATE_REFERENCE_SYSTEM_ID
      1.7.1.7.4. HEIGHT
      1.7.1.7.5. SDH
    
```

```

<POINTS>
  <POINT>
    <ID>P1</ID>
    <NAME>WASHINGTON MONUMENT</NAME>
    <NGS_EQUIPMENT_CODE>BM</NGS_EQUIPMENT_CODE>
    <CODE2 />
    <CODE3 />
    <CODE4 />
    <NGS_PID>HV4442</NGS_PID>
    <DESIGNATION>WASHINGTON MONUMENT</DESIGNATION>
    <COORDINATES>
      <GEODETIC_COORDINATES>
        <GEODETIC_CRN_ID>239</GEODETIC_CRN_ID>
        <EPOCH>2010.0000</EPOCH>
        <LATITUDE>38.88946738</LATITUDE>
        <LONGITUDE>-77.03524008</LONGITUDE>
        <ELLIPSOIDAL_HEIGHT>149.172</ELLIPSOIDAL_HEIGHT>
      </GEODETIC_COORDINATES>
      <GLOBAL_CARTESIAN_COORDINATES>
        <GEODETIC_CRN_ID>252</GEODETIC_CRN_ID>
        <EPOCH>2010.0000</EPOCH>
        <X>1115287.503</X>
        <Y>-4844432.918</Y>
        <Z>3982867.096</Z>
      </GLOBAL_CARTESIAN_COORDINATES>
      <CORRELATION_MATRIX_LOCAL>
        <SDN>0.0029</SDN>
        <SDE>0.0022</SDE>
        <SDU>0.0037</SDU>
        <PNE>0.08202426</PNE>
        <PNU>0.00320246</PNU>
        <PEU>0.00520459</PEU>
      </CORRELATION_MATRIX_LOCAL>
      <ORTHOMETRIC_HEIGHT>
        <VERTICAL_CRN_ID>256</VERTICAL_CRN_ID>
        <EPOCH />
        <HEIGHT>181.3</HEIGHT>
        <SDH>0.01</SDH>
      </ORTHOMETRIC_HEIGHT>
    </COORDINATES>
  </POINT>
    
```

Measurement Settings

```
1.8. MEASUREMENT_SETTINGS
1.8.1. LEVEL_CORRECTIONS
1.8.1.1. ID
1.8.1.2. COLLIMATION_VALUE
1.8.1.3. INSTRUMENT_HEIGHT
1.8.1.4. DATE
1.8.1.5. TEMPERATURE
1.8.1.6. REMARKS
1.8.2. TOTAL_STATION_CORRECTIONS
1.8.2.1. ID
1.8.2.2. CALIBRATION_DATE
1.8.2.3. COMPENSATOR_LONGITUDINAL
1.8.2.4. COMPENSATOR_TRANVERSAL
1.8.2.5. VERTICAL_INDEX
1.8.2.6. HORIZONTAL_COLLIMATION
1.8.2.7. TILTING_AXIS
1.8.2.8. AUTOMATIC_POINTING_HORIZONTAL
1.8.2.9. AUTOMATIC_POINTING_VERTICAL
1.8.2.10. ATMOSPHERIC_CORRECTION_COEFFICIENT
1.8.2.11. REMARK
1.8.3. GNSS_SURVEY_SETUP
1.8.3.1. ID
1.8.3.2. SOLUTION_TYPE
1.8.3.3. PROCESSING_SOFTWARE
1.8.3.4. NAME
1.8.3.5. VERSION
1.8.3.6. SOFTWARE_URL
1.8.3.7. CORRECTOR_FORMAT
1.8.3.7.1. NETWORKRTK
1.8.3.7.2. NAME
1.8.3.7.3. MOUNT_POINT
1.8.3.7.4. TYPE
1.8.3.7.5. IP_ADDRESS
1.8.3.7.6. IP_PORT
```

```
<MEASUREMENT_SETTINGS>
  <LEVEL_CORRECTIONS>
    <ID>LC0001</ID>
    <COLLIMATION_VALUE>0.016</COLLIMATION_VALUE>
    <INSTRUMENT_HEIGHT>1.65</INSTRUMENT_HEIGHT>
    <DATE>2017-05-30T12:12</DATE>
    <TEMPERATURE>20.8</TEMPERATURE>
    <REMARKS />
  </LEVEL_CORRECTIONS>
  <TOTAL_STATION_CORRECTIONS>
    <ID>C0001</ID>
    <CALIBRATION_DATE>2013-11-02</CALIBRATION_DATE>
    <COMPENSATOR_LONGITUDINAL>0.000080556</COMPENSATOR_LONGITUDINAL>
    <COMPENSATOR_TRANVERSAL>0.000086111</COMPENSATOR_TRANVERSAL>
    <VERTICAL_INDEX>0.000044444</VERTICAL_INDEX>
    <HORIZONTAL_COLLIMATION>-0.00020</HORIZONTAL_COLLIMATION>
    <TILTING_AXIS>-0.0006250</TILTING_AXIS>
    <AUTOMATIC_POINTING_HORIZONTAL>0.0000750</AUTOMATIC_POINTING_HORIZONTAL>
    <AUTOMATIC_POINTING_VERTICAL>-0.0004250</AUTOMATIC_POINTING_VERTICAL>
    <ATMOSPHERIC_CORRECTION_COEFFICIENT>294.19</ATMOSPHERIC_CORRECTION_COEFFICIENT>
    <REMARK />
  </TOTAL_STATION_CORRECTIONS>
```

Measurements

- Schema contains support for
 - Leveling
 - Vertical angles
 - Horizontal directions
 - Distances
 - Meteorological metadata

```
<MEASUREMENTS>
  <LEVELING_SECTION>
    <ID>S001</ID>
    <INSTRUMENT_ID>00000049</INSTRUMENT_ID>
    <INSTRUMENT_CORRECTIONS_ID APPLIED="1">C00001</INSTRUMENT_CORRECTIONS_ID>
    <INITIAL_POINT_ID ROD="R001">1207</INITIAL_POINT_ID>
    <TERMINAL_POINT_ID ROD="R001">1223</TERMINAL_POINT_ID>
    <ELEVATION_DIFFERENCE>23.40089</ELEVATION_DIFFERENCE>
    <RUNNING_DISTANCE>1120.3</RUNNING_DISTANCE>
    <RUNNING_IMBALANCE>-0.1</RUNNING_IMBALANCE>
    <ORDER>1</ORDER>
    <CLASS>2</CLASS>
    <OBSERVATION_TIME>
      <BEGIN>2017-05-30T12:12</BEGIN>
      <END>2017-05-30T14:02</END>
    </OBSERVATION_TIME>
    <PROBES SOURCE="Observed">
      <PROBE_TEMP HEIGHT="0.5">22.9</PROBE_TEMP>
      <PROBE_TEMP HEIGHT="1.5">22.9</PROBE_TEMP>
    </PROBES>
    <INTERMEDIATE_SETUPS TOTAL="20">
      <SETUP>
        <ID>S001_1</ID>
        <POINT_ID></POINT_ID>
        <INSTRUMENT_HEIGHT>1.68</INSTRUMENT_HEIGHT>
        <PROBES SOURCE="Observed">
          <PROBE_TEMP HEIGHT="0.5">20.2</PROBE_TEMP>
          <PROBE_TEMP HEIGHT="1.5">20.2</PROBE_TEMP>
        </PROBES>
        <BACKSIGHT ROD="R001">
          <POINT_ID>2040</POINT_ID>
          <ROD_READING>0.93095</ROD_READING>
          <NUMBER_OF_MEASUREMENTS>5</NUMBER_OF_MEASUREMENTS>
          <STANDARD_DEVIATION>0.05</STANDARD_DEVIATION>
          <SIGHT_DISTANCE>30.53</SIGHT_DISTANCE>
          <OBSERVATION_TIME>2017-05-30T12:12</OBSERVATION_TIME>
        </BACKSIGHT>
      </SETUP>
    </INTERMEDIATE_SETUPS>
  </LEVELING_SECTION>
</MEASUREMENTS>
```

Reductions

- This section relates *measurements* (raw field data) to *observations* (data)
- Contains corrections to measurements from atmospheric refraction, deflections of the vertical, instrument height, and target heights
- Fields have not yet been defined and this section will not be part of the alpha release

Observations

- This section is intended for data that is ready for a three-dimensional least-squares adjustment
- Observations should be mark-to-mark and corrected for deflections of the vertical and atmospheric refraction to the local geodetic frame
- Supports
 - GNSS vectors
 - Vertical angles
 - Distances
 - Horizontal angles, directions, and azimuths
 - Leveling

```

<OBSERVATIONS>
  <HORIZONTAL_DIRECTIONS> <!-- for horizontal directions, must have a minimum of two sights-->
    <HORIZONTAL_DIRECTION_SET>
      <CLASSICAL_SET_ID>co7</CLASSICAL_SET_ID>
      <REDUCTIONS_ID />
      <INSTRUMENT_POINT_ID>P1</INSTRUMENT_POINT_ID>
      <SIGHT>
        <SIGHT_POINT_ID>P5</SIGHT_POINT_ID>
        <SIGHT_ID>CS0007</SIGHT_ID>
        <ANGLE>2.5723611111</ANGLE>
        <SIGMA>0.0003294527</SIGMA>
        <REPLICATIONS>4</REPLICATIONS>
        <REMARK/>
      </SIGHT>
      <SIGHT>
        <SIGHT_POINT_ID>P6</SIGHT_POINT_ID>
        <SIGHT_ID>CS0007</SIGHT_ID>
        <ANGLE>200.5723611111</ANGLE>
        <SIGMA>0.0003294527</SIGMA>
        <REPLICATIONS>4</REPLICATIONS>
        <REMARK/>
      </SIGHT>
    </HORIZONTAL_DIRECTION_SET>
  </HORIZONTAL_DIRECTIONS>
  <HORIZONTAL_ANGLES>
    <HORIZONTAL_ANGLE>
      <CLASSICAL_SET_ID>co7</CLASSICAL_SET_ID> <!-- for horizontal angles, there must be a backsight and there could be only 1 sight -->
      <REDUCTIONS_ID />
      <INSTRUMENT_POINT_ID>P1</INSTRUMENT_POINT_ID>
      <BACKSIGHT_POINT_ID>P2</BACKSIGHT_POINT_ID>
      <SIGHT_POINT_ID>P5</SIGHT_POINT_ID>
      <SIGHT_ID>CS0007</SIGHT_ID>
      <ANGLE>2.5723611111</ANGLE>
      <SIGMA>0.0003294527</SIGMA>
      <REPLICATIONS>4</REPLICATIONS>
      <REMARK/>
    </HORIZONTAL_ANGLE>
    <HORIZONTAL_ANGLE>
      <CLASSICAL_SET_ID>co7</CLASSICAL_SET_ID>
      <REDUCTIONS_ID />
      <INSTRUMENT_POINT_ID>P1</INSTRUMENT_POINT_ID>
      <BACKSIGHT_POINT_ID>P2</BACKSIGHT_POINT_ID>
      <SIGHT_POINT_ID>P4</SIGHT_POINT_ID>
      <SIGHT_ID>CS0008</SIGHT_ID>
      <ANGLE>274.8460833333</ANGLE>
      <SIGMA>0.0003375505</SIGMA>
      <REPLICATIONS>7</REPLICATIONS>
      <REMARK/>
    </HORIZONTAL_ANGLE>
    <HORIZONTAL_ANGLE>
      <CLASSICAL_SET_ID>co7</CLASSICAL_SET_ID>
      <REDUCTIONS_ID />
      <INSTRUMENT_POINT_ID>P1</INSTRUMENT_POINT_ID>
      <BACKSIGHT_POINT_ID>P2</BACKSIGHT_POINT_ID>
      <SIGHT_POINT_ID>P3</SIGHT_POINT_ID>
      <SIGHT_ID>CS0010</SIGHT_ID>
      <ANGLE>128.4798134921</ANGLE>
      <SIGMA>0.0003238283</SIGMA>
      <REPLICATIONS>7</REPLICATIONS>
      <REMARK/>
    </HORIZONTAL_ANGLE>
  </HORIZONTAL_ANGLES>

```

Corbin Quad Survey

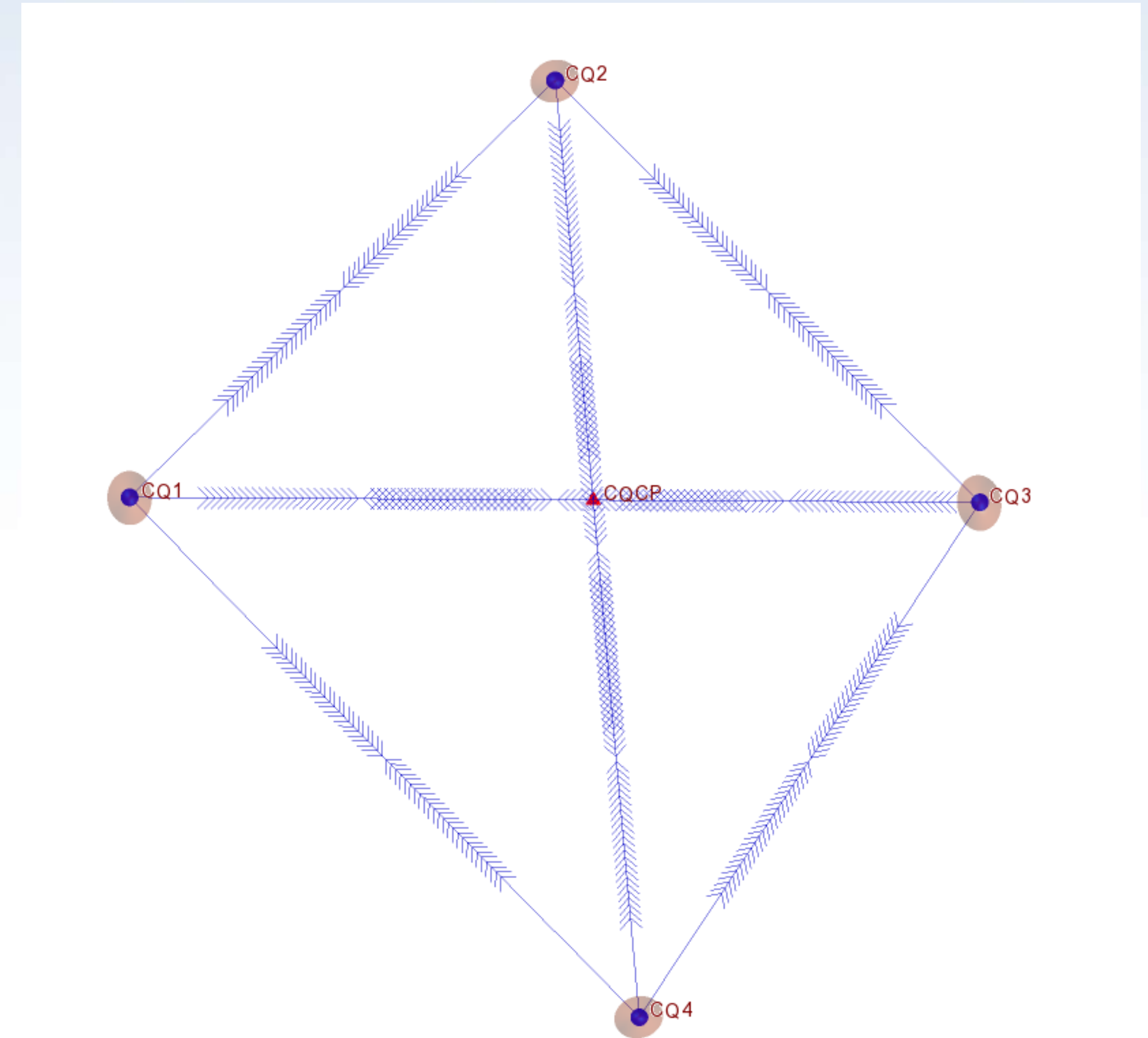
NGS has executed a highly redundant survey conducted over multiple days on a set of five points at the NGS Testing and Training Center in Woodford, VA

Supports:

- Least-squares adjustment testing
- Atmospheric refraction research
- Geodetic astronomy research

Techniques used:

- Simultaneous GNSS
- Total station angles and distances
- Leveling
- Astronomic azimuths and deflections of the vertical
- Detailed vertical temperature profiles



Alpha Release

- The alpha version of GDX will be available on the NGS alpha website in the coming weeks
- As an *alpha* product, this initial version will be incomplete but available for early feedback
- This website will include documentation and example files, including the Corbin Quad Survey

alpha.ngs.noaa.gov

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Data Formats
Geodetic Data Exchange (GDX)

Geodetic Data Exchange (GDX)

Background
GDX aims to provide a standard file format for exchanging GNSS vectors derived from varying GNSS survey methods and manufacturer hardware. The file format includes all of the necessary data of a GNSS vector for inclusion in a survey network for least squares adjustment, as well as crucial metadata. The format is meant for any type of GNSS vector, whether it was derived in a real-time kinematic (RTK) survey or from post-processed kinematic (PPK) processing. The goal for developing GDX is so that vector data can be uploaded to OPUS-Post, NGS accounts feedback on this file format. Please send comments to NGS.Feedback@noaa.gov.

The Receiver Independent Exchange format (RINEX) was developed three decades ago as a means for sharing static GNSS data. Unfortunately, a similar standard file format for GNSS vectors does not currently exist. A GNSS vector is a mathematical representation of the processing and offsetting of raw GNSS data collected by two receivers, one at each end of a baseline. Such vectors are commonly put in a survey network for least squares adjustment. However, vector file formats are largely technique and vendor specific. To this end, NGS is proposing the GDX file format for exchanging all types of GNSS vectors, whether derived as part of a real-time kinematic (RTK) survey or from post-processed kinematic (PPK) processing.

GDX Contents
The links below provide detailed documentation on all of the elements and data types in the GDX file format, an example GDX file, and a schema with information on restrictions, optional elements, and more.

- [Documentation](#)
- [Example GDX file, project Aug 18, Aug 19, Aug 20, Aug 21, Aug 22](#)
- [GDX Schema](#)

GDX elements include but are not limited to the following:

- Station name, Earth-Centered, Earth-Fixed (ECEF) vector components
- Variances and covariances of vector components
- Reference frame information
- Date and time (UTC) of the observation
- Azimuth coordinates for the end points of each vector
- Receiver and antenna type
- RTK and post-processed kinematic (PPK) settings / parameters
- Quality control metadata (e.g., PPDOP, number of satellites used, etc.)

Feedback
Ultimately, the goal is for industry and academia to adopt GDX for storing and sharing GNSS vector data, in a similar manner to how RINEX has been adopted for static GNSS data. Thus, NGS is requesting comments and feedback from all interested parties, which can be emailed to NGS.Feedback@noaa.gov.

NGS is interested in feedback on the following:

- Important data that is missing in the proposed format
- Extraneous or unnecessary data that is currently in the format
- Similar standard file formats that may already be available for use

TELL US WHAT YOU THINK!

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What's Next

- Support for measurement reductions
- Support for tape and other classical measurement types
- Support for astronomical measurements, including azimuths and deflections of the vertical
- Support for relative gravity

Questions?

ryan.hardy@noaa.gov