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Augmenting Data Exchange Formats for OPUS of the Future

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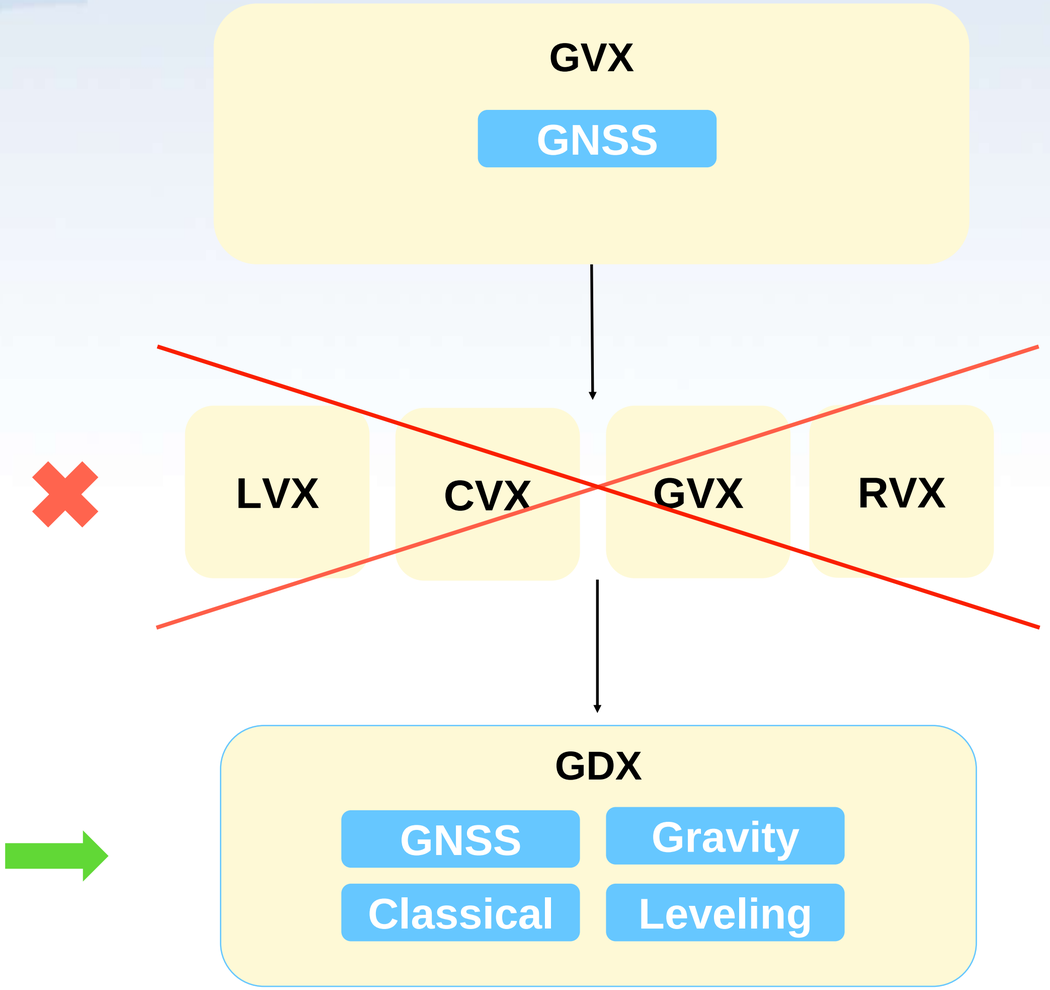
FIG Working Week

Geodetic Data Exchange (GDX)

- GDX is an XML-based data format that will be the input format for OPUS
- GDX will be the successor to the GNSS Vector Exchange (GVX) format and is designed to be backwards-compatible with Bluebook
- GDX 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_CRS
        1.4.1.1.   ID
        1.4.1.2.   CODE
        1.4.1.3.   NAME
        1.4.1.4.   REMARK
    1.4.2.   VERTICAL_CRS
        1.4.2.1.   ID
        1.4.2.2.   CODE
        1.4.2.3.   NAME
        1.4.2.4.   REMARK
```

```
<COORDINATE_REFERENCE_SYSTEMS>
        <GEODETIC_CRS>
                <ID>239</ID>
                <CODE />
                <NAME>NAD 83 (2011) Epoch 2010 - LatLonEHt</NAME>
                <REMARK />
        </GEODETIC_CRS>
        <GEODETIC_CRS>
                <ID>252</ID>
                <CODE />
                <NAME>NAD 83 (2011) Epoch 2010 - XYZ</NAME>
                <REMARK />
        </GEODETIC_CRS>
        <VERTICAL_CRS>
                <ID>256</ID>
                <CODE />
                <NAME>NAVD88 - OHt</NAME>
                <REMARK />
        </VERTICAL_CRS>
</COORDINATE_REFERENCE_SYSTEMS>
```

Units

1.5. UNITS

- 1.5.1. LINEAR
- 1.5.2. ANGLE
- 1.5.3. TEMPERATURE
- 1.5.4. RELATIVE_HUMIDITY
- 1.5.5. WIND_SPEED

```
<UNITS>
        <LINEAR>meters</LINEAR>
        <ANGLES>decimal degrees</ANGLES>
        <TEMPERATURE>Celsius</TEMPERATURE>
        <PRESSURE>millibar</PRESSURE>
        <RELATIVE_HUMIDITY>percent</RELATIVE_HUMIDITY>
        <WIND_SPEED>kilometers per hour</WIND_SPEED>
</UNITS>
```

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_CRS_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_CRS_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_CRS_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_CRS_ID>239</GEODETIC_CRS_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_CRS_ID>252</GEODETIC_CRS_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_CRS_ID>256</VERTICAL_CRS_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>
```

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

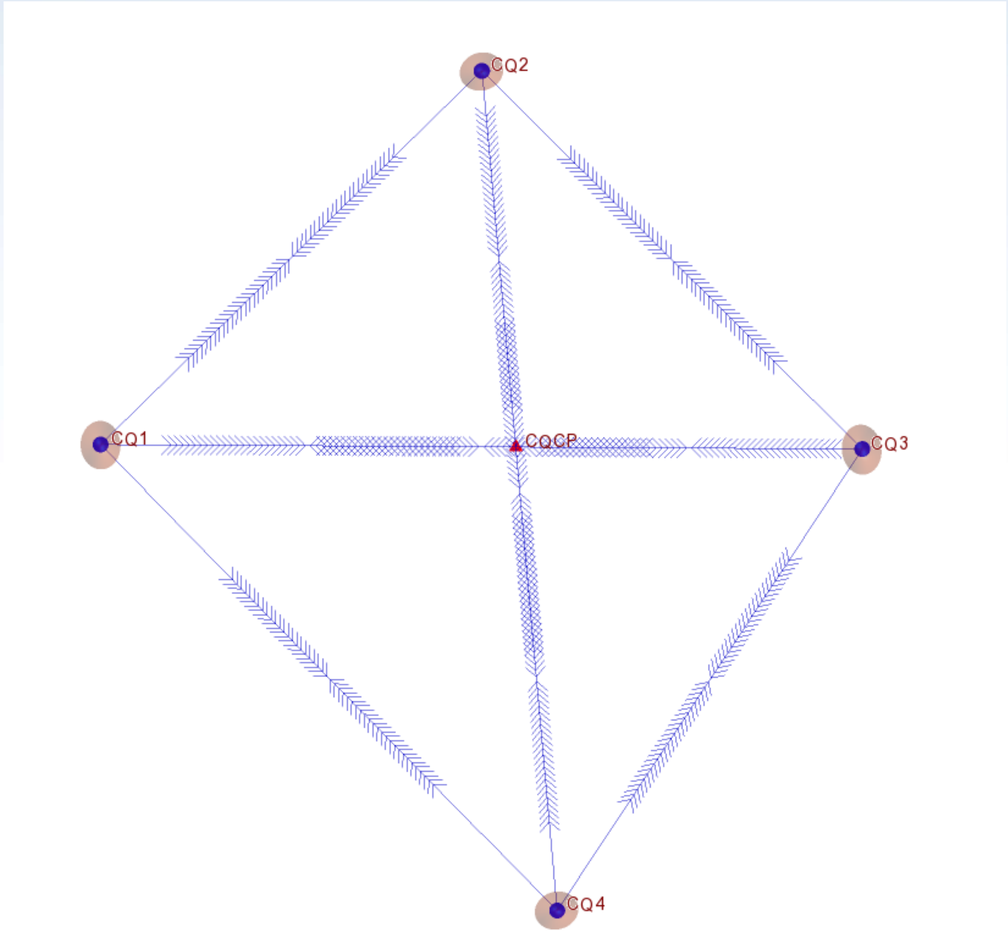
NGS has executed a highly redundant survey conducted over multiple days on a set of five points at the NGS Testing and Training Center in Woodford, VA

Supports:

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

Techniques used:

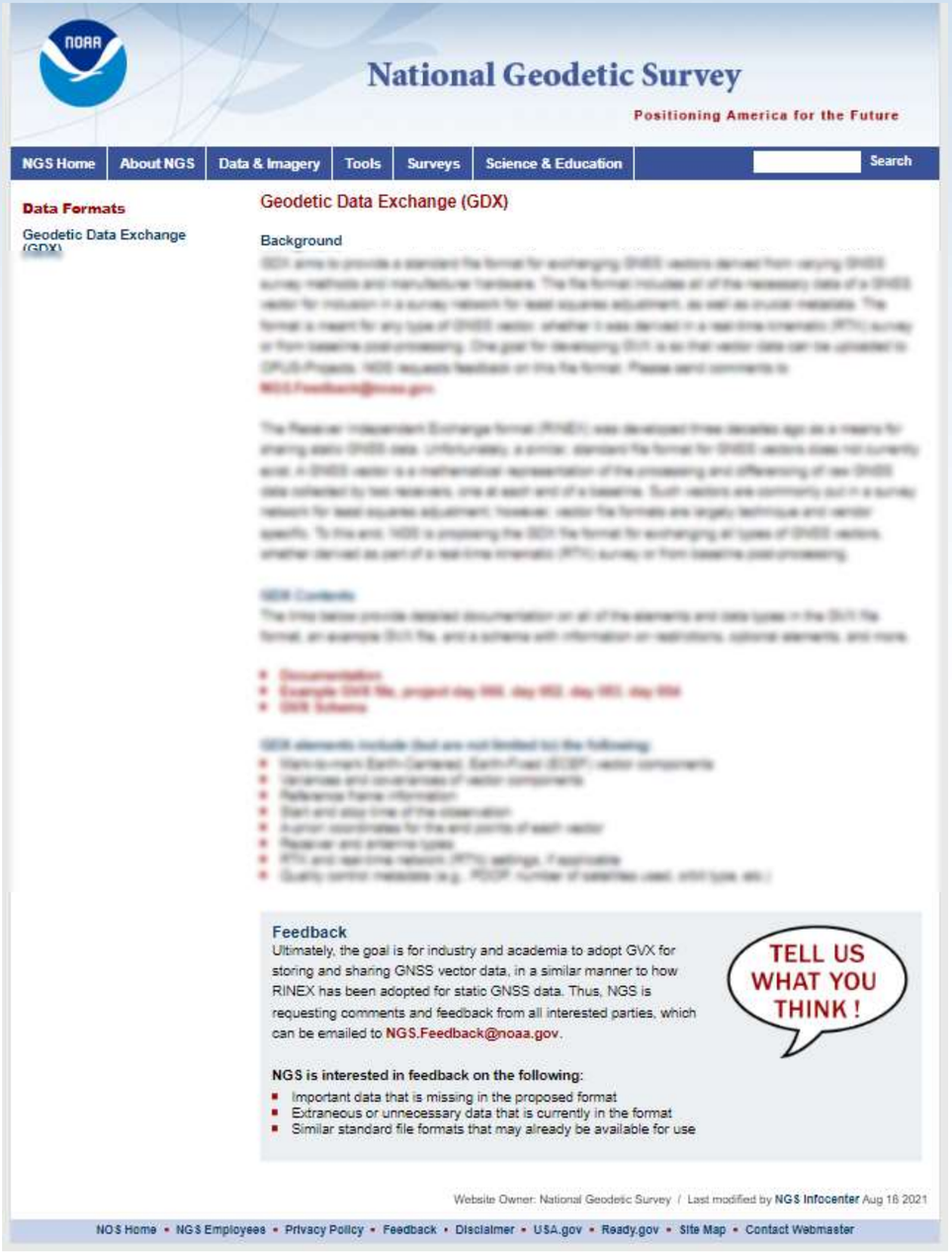
- Simultaneous GNSS
- Total station angles and distances
- Leveling
- Astronomic azimuths and deflections of the vertical
- Detailed vertical temperature profiles



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



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?

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