Standard Data File Formats for GNSS, Total Stations, Automatic Levels, and Relative Gravimeters

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May 6, 2021

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Outline

1. Background on why we need standard file formats
2. Problem statement and objectives
3. RINEX 3 as standard for raw GNSS data
4. Other XML-based file formats as standards
    1. GVX – GNSS vectors
    2. CVX – Classical (angles/distances)
    3. LVX – Leveling
    4. RGX – relative gravity

Why Standard File Formats?

- Differing instrument manufacturers output data in varying file formats (often proprietary, closed-source)
- Standardization benefits:
  - Broadens use; easier to work with by others who will use the data
  - Easier to share with others
  - Reduces the need to convert from one format to another
  - Data in proprietary format can be converted to open, standard format
  - Increases likelihood critical metadata is captured and accurate; significant figures are preserved
  - Lengthens the preservation of the data
  - Can be made machine-readable

Problem Statement

NGS is developing:

1. **M-PAGES** – baseline processing engine for multi-GNSS data
   - M-PAGES provides its best solutions with RINEX 3
   - RINEX 3 is the international standard for raw GNSS data, and many IGS stations only provide RINEX 3 files
   - But the NOAA CORS Network currently archives data in RINEX 2, and many current workflows at NGS process RINEX 2 data files
2. **OPUS** – software for managing, processing, and adjusting survey data
   - (Note M-PAGES will become the baseline processing engine in OPUS)
   - OPUS-Projects v. 5 supports GNSS vectors, such as Real-time Kinematic (RTK) vectors
   - OPUS v. 6 will support survey data from total stations, automatic levels, and relative gravimeters
   - But there is a lack of a well-accepted, industry-wide standard file format for GNSS vectors, total stations, levels, and gravimeters

Objectives

1. Adopt RINEX 3 as the standard file format for raw GNSS data
   - Require submission/uploading of RINEX 3 data files to NGS

2. Develop new standard file formats:
   - GVX: GNSS Vector Exchange Format
   - CVX: Classical Vector Exchange Format (angles, distances)
   - LVX: Leveling Vertical Exchange Format
   - RGX: Relative Gravity Exchange Format

Background on RINEX 3

- Originally released in 2007
- The international scientific standard for exchanging raw GNSS data
- Endorsed by the IGS and RTCM
- Actively maintained and updated (current version is 3.05)
- Supports all GNSS signals and constellations
- Enables unambiguous use of all observables and application of modern GNSS products (e.g., Bias-SINEX)
- M-PAGES is designed to best support RINEX 3 data files, although it can also process RINEX 2 data files.
  - *If you want the best multi-GNSS solution, you will want to work with RINEX 3*

NGS and RINEX 3

- In the near future (*date to be determined*), NGS will only support RINEX 3 for its products and services which rely upon raw GNSS data, with some exceptions
- NGS will be releasing a Federal Register Notice for notification and public commenting

NOAA CORS Network and RINEX 3

- Each CORS must be capable of providing:
  - RINEX 3 file
  - Binary exchange (BINEX) file
  - Raw proprietary data file

For QC purposes and/or when communication link is too slow to upload RINEX 3 directly

For QC purposes

- NGS will archive the RINEX 3 files at each CORS
  - When necessary, NGS will convert the BINEX file to RINEX 3
  - Raw GNSS data currently stored by NGS will remain in its earlier version of RINEX (no up-conversion)

OPUS and RINEX 3

- NGS will recommend and encourage use of RINEX 3 for OPUS
  - Provides the best multi-GNSS solutions
- NGS will continue to allow use of RINEX 2 in OPUS for legacy data and equipment
- NGS will discontinue support of non-RINEX data submissions to OPUS

Development of XML-Based Standard File Formats

XML-Based Standard File Formats

Measurement Type	File Format	File Type	Current Status	Use at NGS
Reduced GNSS data (GNSS vector)	**GVX**	XML	Released final version 1.0 on 2/04/2021	OPUS-Projects v.5, OPUS v.6
Differential leveling (height differences)	**LVX**	XML	Under development. Version 0.3 under review	OPUS v.6
Classical (angles, distances)	**CVX**	XML	Under development. Version 0.3 under review	OPUS v.6
Relative gravity (gravity differences)	**RGX**	XML	Planned for 2022	OPUS v.6

OPUS-Projects v. 5

- Inclusion of previously processed GNSS vectors
  - Single-base RTK vectors
  - Network RTK vectors
  - Vectors processed in other software
- Allows QA/QC of uploaded vectors
- Automatically "weights" uploaded vectors in a network least squares adjustment
- Final adjustment results can be submitted to NGS for publication
- Facilitates collection of RTK data on bench marks; helps with building transformation tools for the modernized NSRS
- Released to Beta for external testing. Available at: https://beta.ngs.noaa.gov/OPUS-Projects/OpusProjects.shtml
- Webinar scheduled for May 20, 2021

GNSS Vector EXchange Format (GVX)

Website: https://www.ngs.noaa.gov/data/formats/GVX/index.shtml

- Detailed documentation
- Schema (XSD)
- Example vector file

GVX is written in Extensible Markup Language (XML)

- Designed to store and carry data in plain text format
- Flexible representation of arbitrary data structures
- Extensible – new elements can be added later without breaking applications
- Both machine-readable and human-readable
- Schemas can be used to define "must haves" and "should haves"

GNSS Vector EXchange Format (GVX)

Timeline

- Solicited internal and external feedback for GVX since 8/2019
- Introduced to industry in 10/2019; solicited feedback
- Addressed all comments and feedback
- Released version 1.0 to industry in 02/2021

Some important details due to feedback from industry:

- All start and stop times must be in GPS time
- Distance must be in meters
- Angles must be in decimal degrees
- Follow IGS naming conventions for antenna names
- Follow ISO Geodetic Register for reference systems

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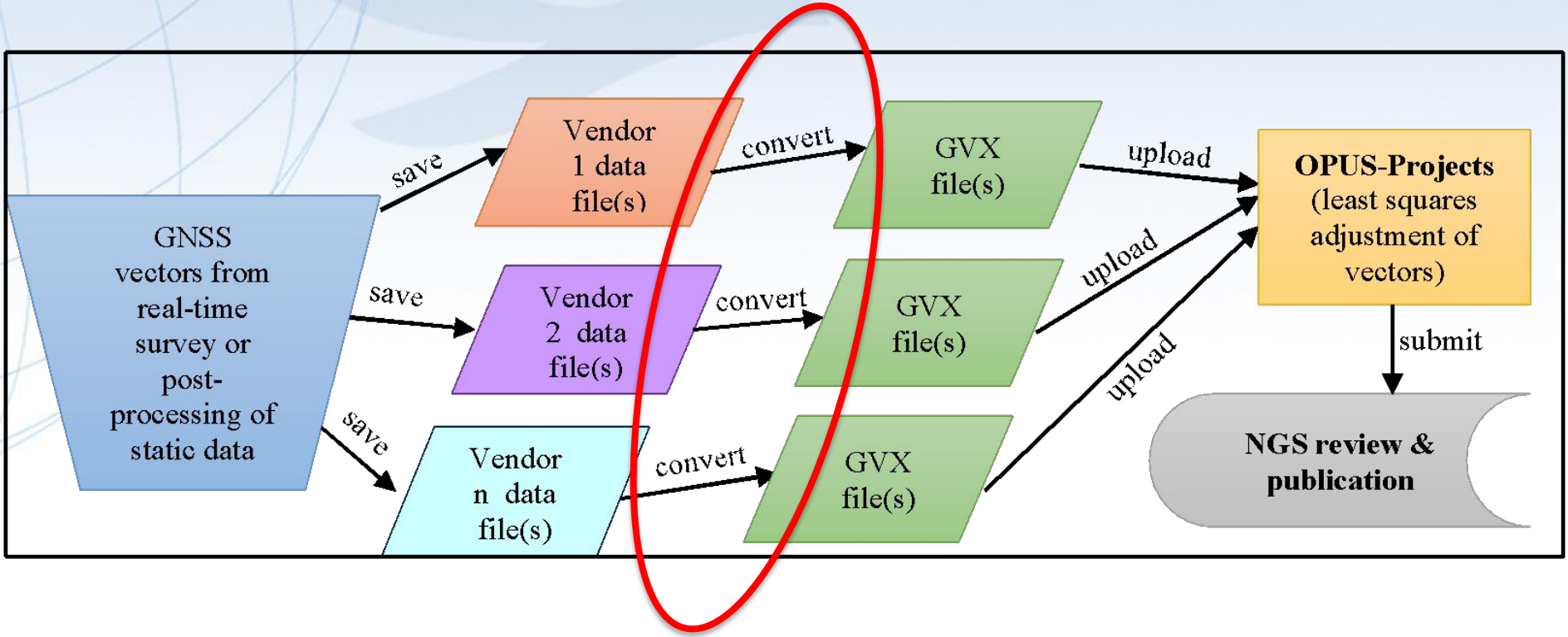
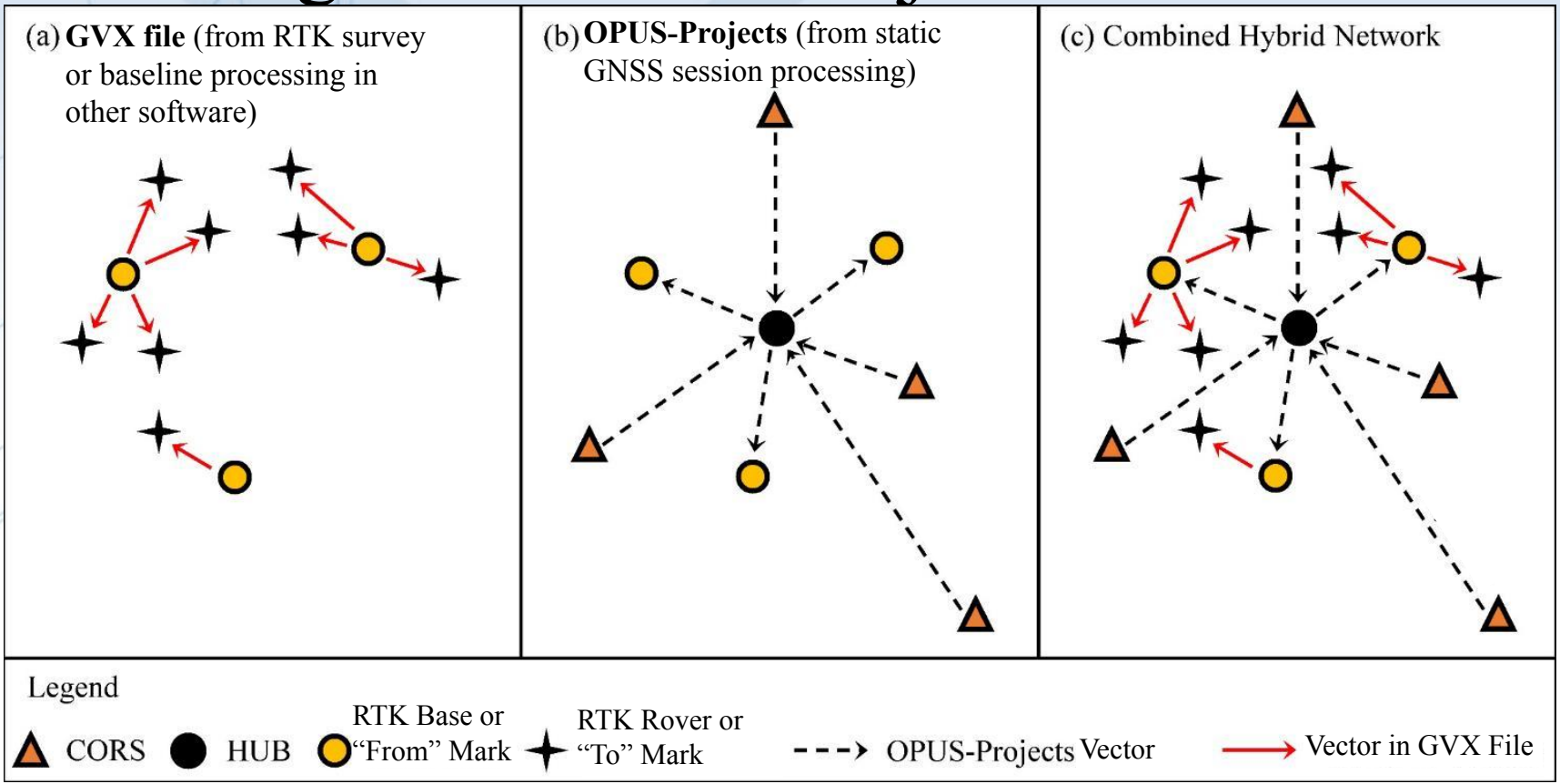
Industry Invited to Provide Feedback

- Released GVX v. 1.0 released to industry on February 4, 2021
- Over 30 people attended mtg

How will NGS use GVX?

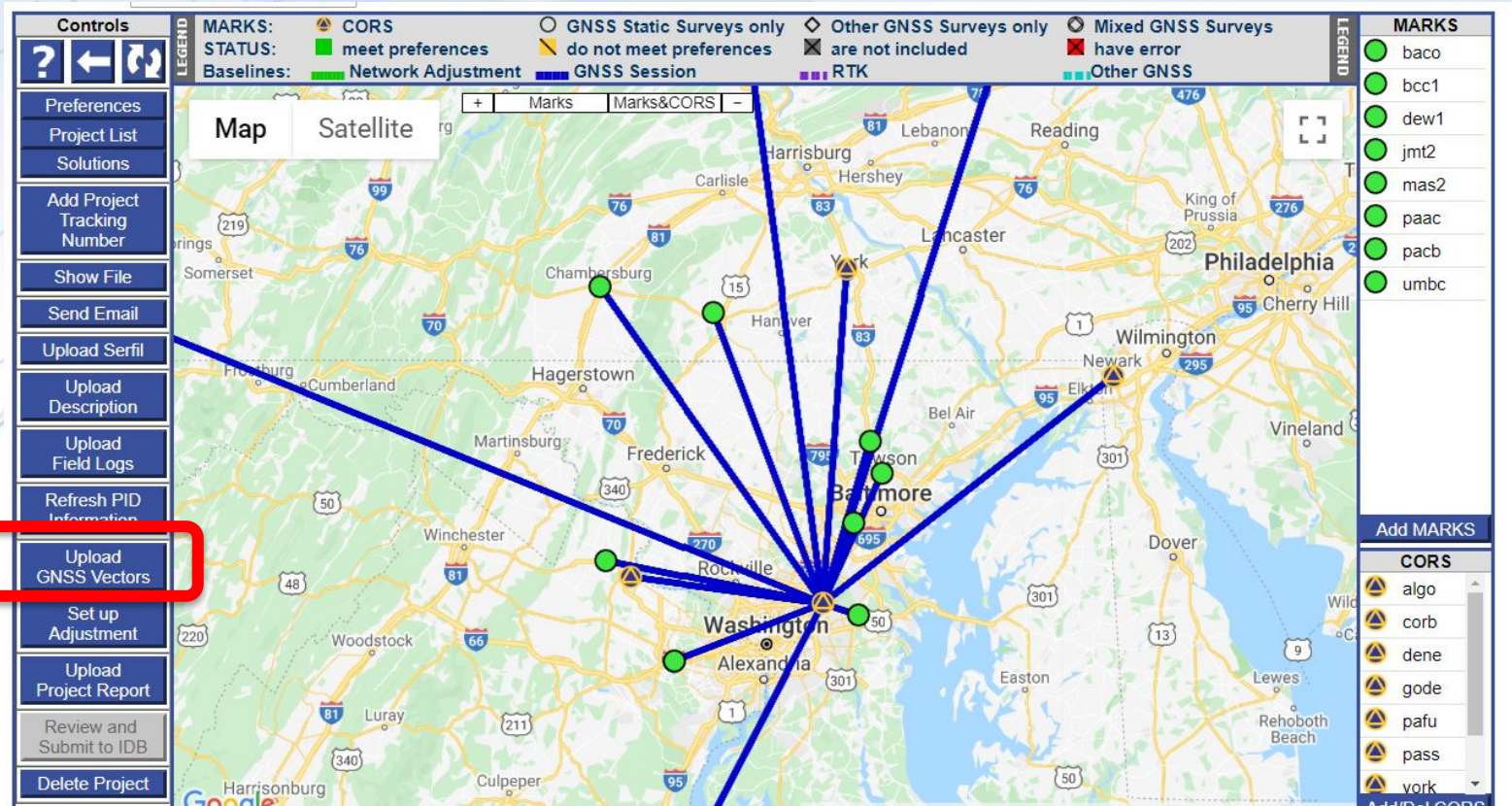


Design for OPUS-Projects and GVX

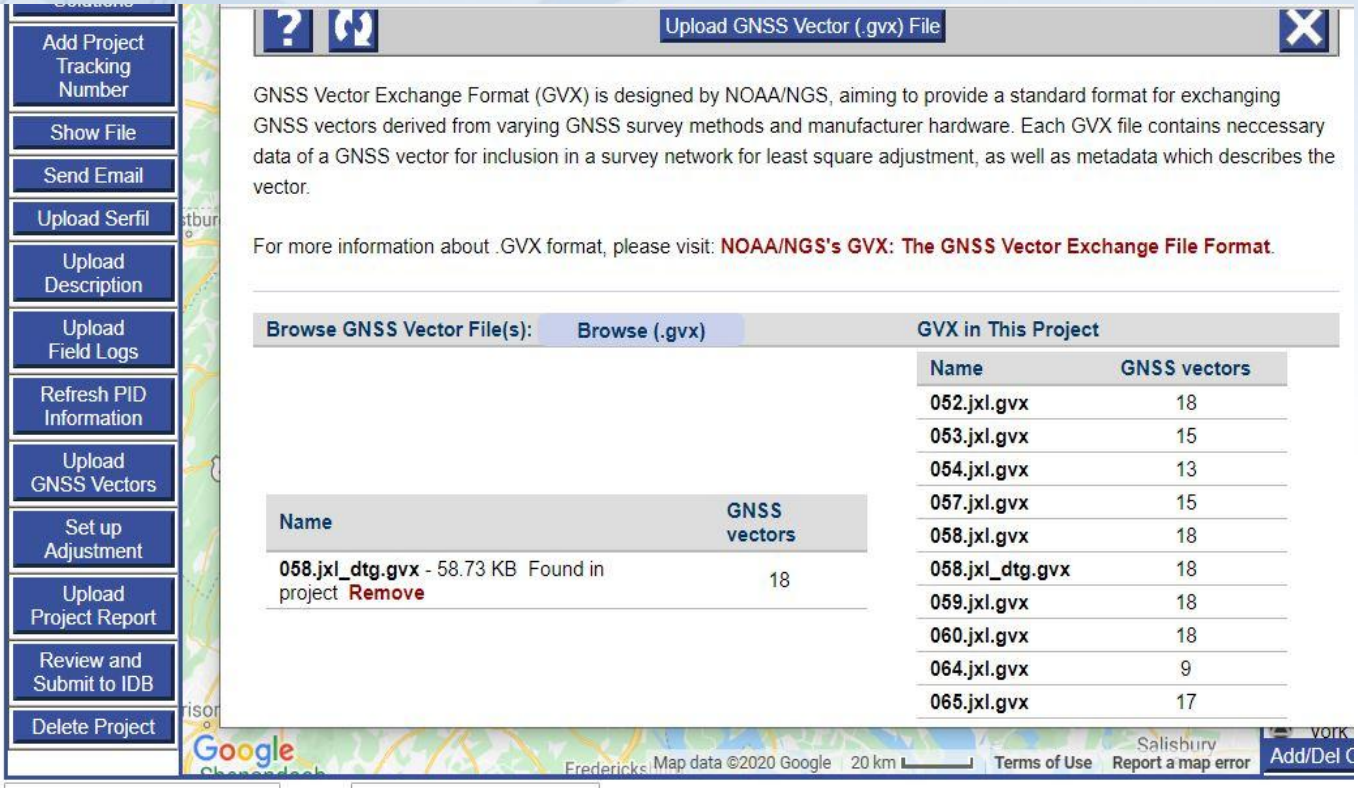


[Adapted from Weaver et al. 2018]

Step 1: Upload Static GNSS Data Collected at Base Stations; Post-process with CORSs

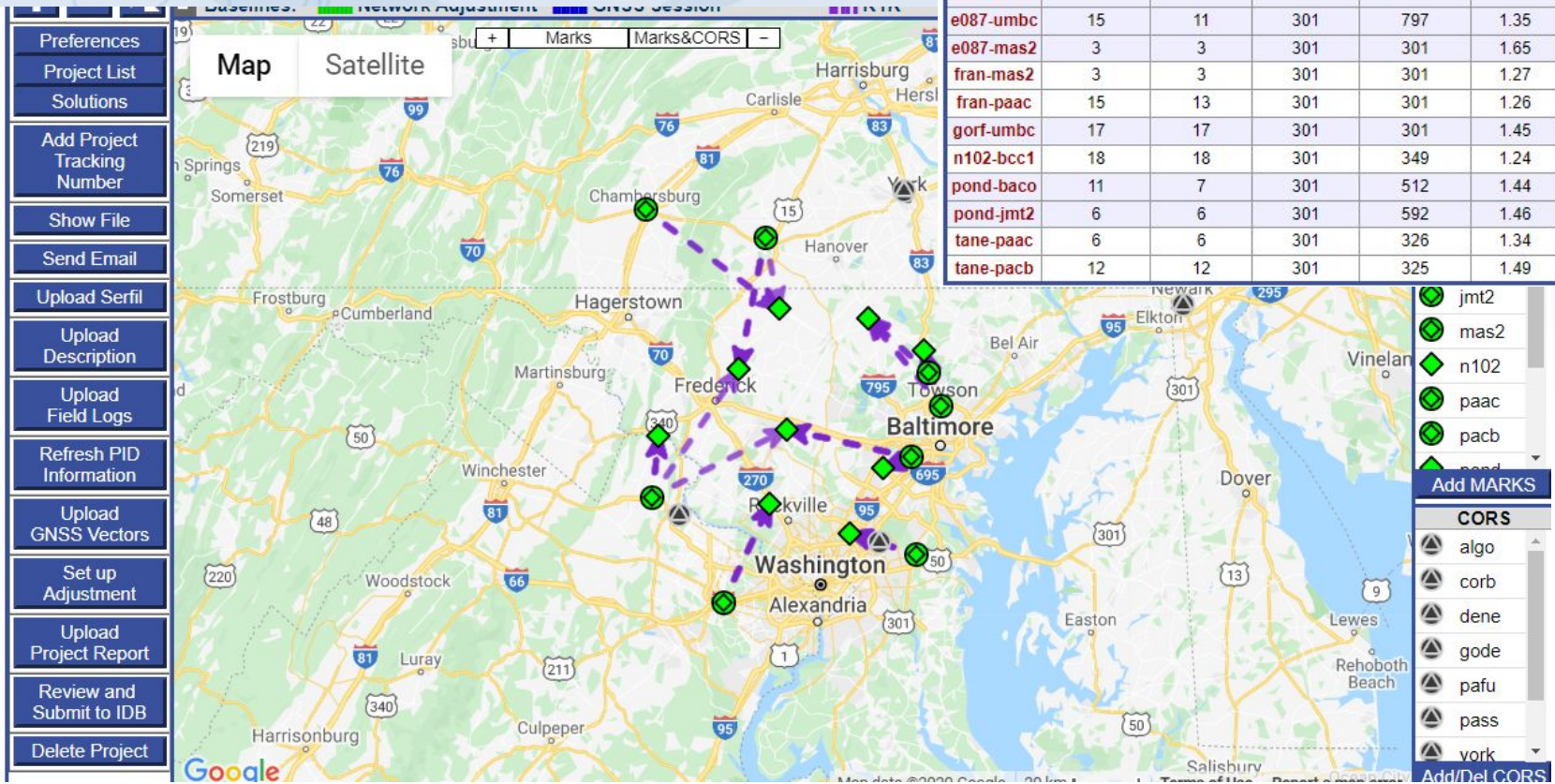


Step 2: Upload GVX Files (Vectors)

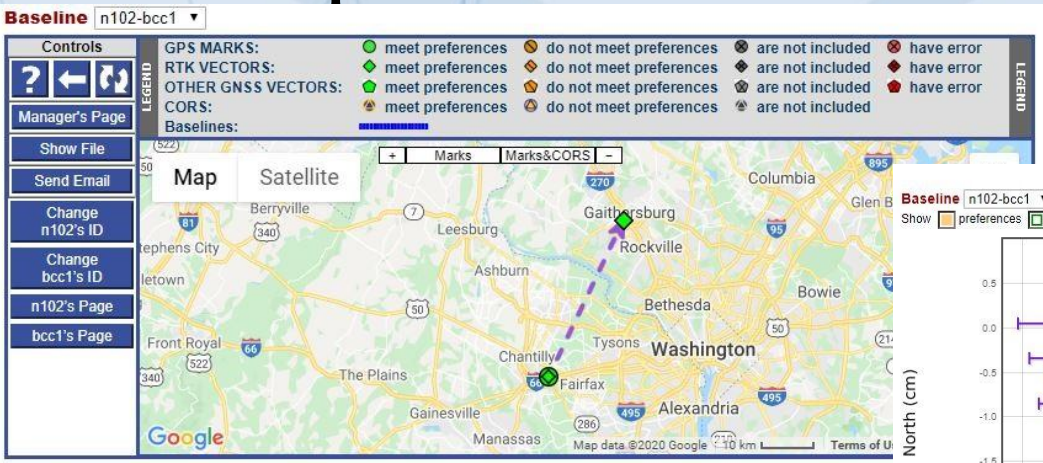


Step 2: Upload GVX Fi

Baselines	GVX Baseline Statistics					
	vector count	vector used	Span Min (s)	Span Max (s)	PDOP Min	PDOP Max
bell-jmt2	6	6	301	319	1.32	1.66
bell-baco	13	13	301	362	1.26	2.12
brun-mas2	18	12	301	301	1.36	2.3
calv-dew1	16	15	301	333	1.36	2.2
e087-umbc	15	11	301	797	1.35	4.31
e087-mas2	3	3	301	301	1.65	2.34
fran-mas2	3	3	301	301	1.27	1.38
fran-paac	15	13	301	301	1.26	3.34
gorf-umbc	17	17	301	301	1.45	2.27
n102-bcc1	18	18	301	349	1.24	2
pond-baco	11	7	301	512	1.44	2.35
pond-jmt2	6	6	301	592	1.46	2.4
tane-paac	6	6	301	326	1.34	2.3
tane-pacb	12	12	301	325	1.49	2.09



Step 3: Review and QA/QC Vectors



Baseline n102-bcc1 **Occupation Summary** Save

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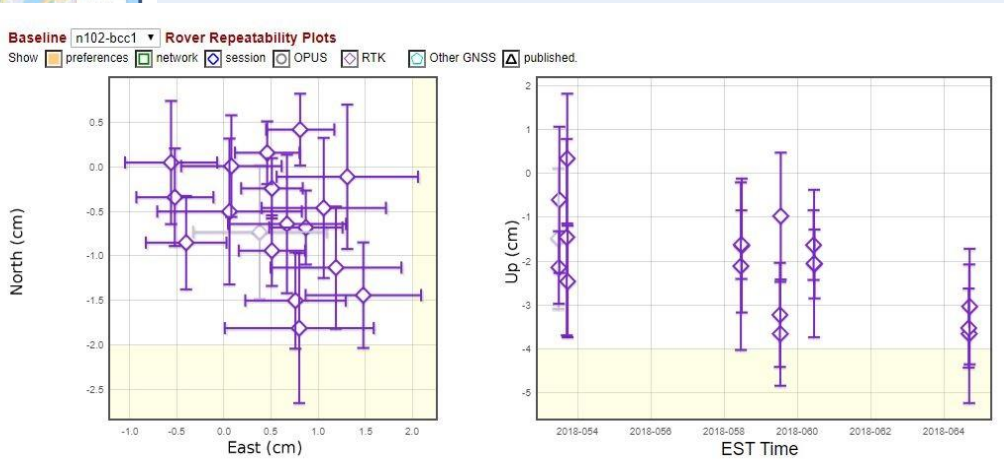

Baseline n102-bcc1 **Solution Quality Indicators** Save USE Changes

USE	VECTOR	GVX ID	ROVER ANTENNA		ROVER HEIGHT (m)	EPOCHS USED	EPH TYPE	PDOP	SATELLITES USED	TYPE	SOLUTION TYPE	PROCESSOR NAME	MOUNT POINT	LAT (m)	LON (m)	HGT (m)
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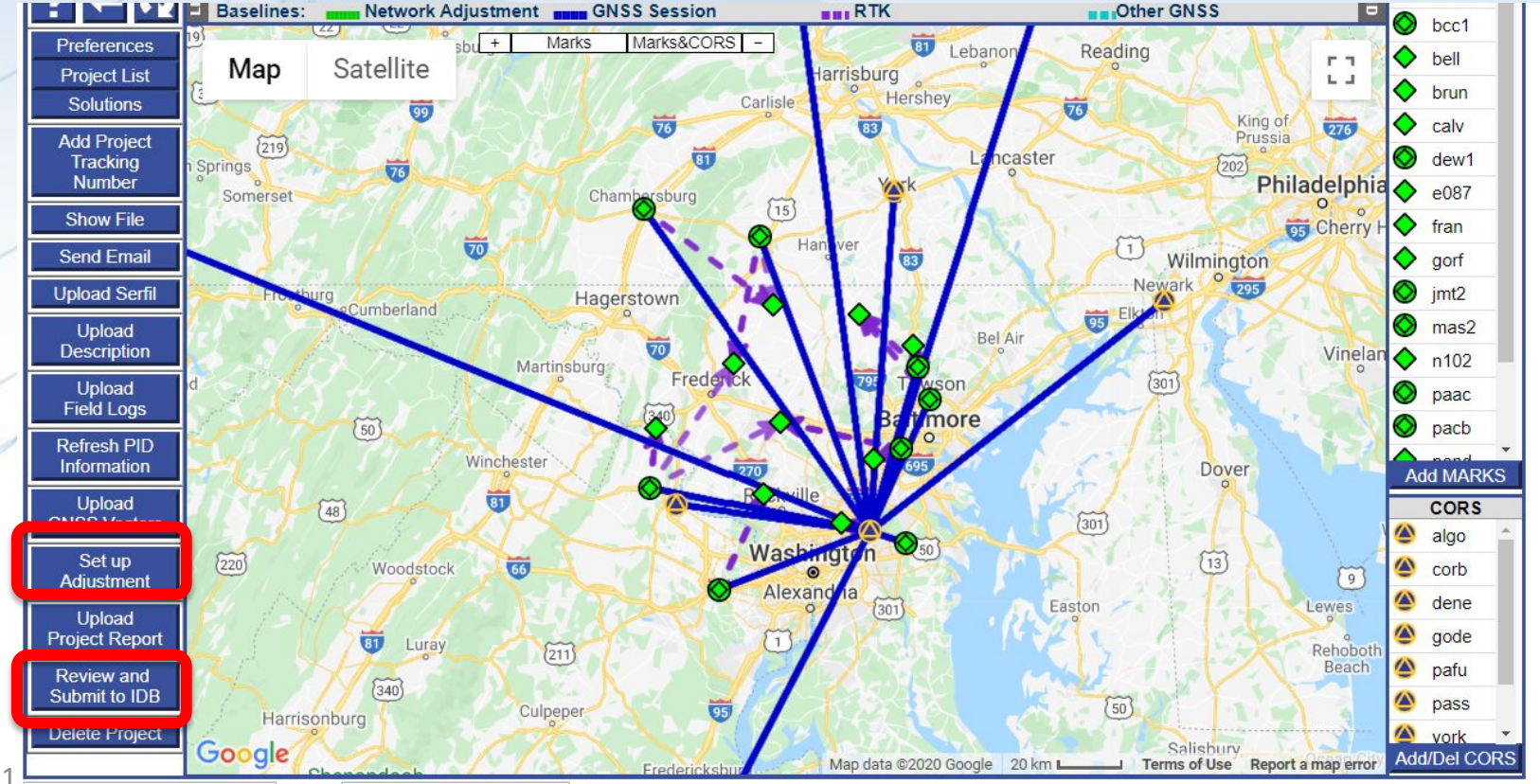
☑	V7	058.jxl.gvx	TRMR10	NONE	2.000	301	Ultra-rapid predicted	1.30	14=C0:E0:G9:J0:R5	Fixed	NetworkRTK	Trimble VRS3Net	VRS_RTCM3	-0.011	0.003	-0.005

Step 4: Combine Post-processed Vectors and Uploaded Vectors (from GVX) in Survey Network for Adjustment



Other XML-based File Formats

- GVX sets template for other XML standard file formats
  - CVX = classical (angles/distances)
  - LVX = leveling
  - RGX = relative gravity
- Desire industry to adopt all of these common file formats, and goal is to make OPUS v.6 capable of using them
- Aim to take these files to international community for adoption or inclusion in GeodesyML

CVX: Classical Vector Exchange

1. SOURCE_DATA
2. PROJECT_INFORMATION
3. REFERENCE_SYSTEM
4. UNITS *(global definition of units in the file)*
5. CLASSICAL_EQUIPMENT *(instrument make/model, white paper specifications, target make/model)*
6. INSTRUMENT_CORRECTIONS (*compensator, vertical index, automatic pointing, collimation, etc.)*
7. POINT
8. CLASSICAL_SET *(weather, ppm, horizontal and vertical angles, distance, sigmas, instrument faces, target offset, measurement mode, distance type)*

LVX: Leveling Vertical Exchange

1. SOURCE_DATA
2. PROJECT_INFORMATION
3. REFERENCE_SYSTEM
4. VERTICAL_DATUM *(datum for heights with IDs per ISO Geodetic Registry)*
5. UNITS
6. LEVELING_EQUIPMENT *(instrument make/model, serial number, white paper specifications, and rod(s) make/model/material, white paper specs., calibration info.)*
7. COLLIMATION *(applied collimation value from peg test)*
8. FIELD_ACCURACY_TEST *(results of a field test on accuracy of leveling equip.)*
9. POINT
10. LEVELING_SECTION *(elevation difference, running distance, running imbalance, operator, start and stop time, temp. probes, maximum instrument height, weather, total setups, leveling method, individual setups with backsight, foresight, stadia wires, and reading mode)* □*(NOTE: supports electronic, optical, 3-wire, and micrometer)*

Summary

- Modern receivers need to output RINEX 3
- Requesting industry to adopt these XML-based file formats
  - GVX: GNSS Vectors (released in 02/2021) ← Desire industry to build convertors to GVX
  - CVX: Classical (angles/distances)
  - LVX: Leveling
  - RGX: Relative Gravity

  Plan to release in 2022; desire industry to provide feedback
  - Schemas will be written for all
  - Feedback and ideas are welcome!

Questions?

- Daniel.Gillins@noaa.gov