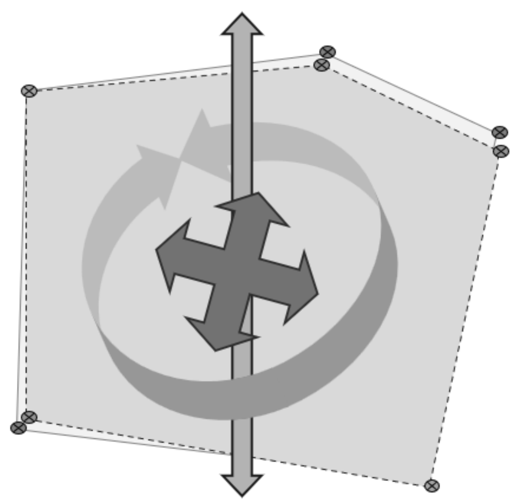
GNSS Localization/Calibration

Summary

In short, ‘Localization’ (which some GNSS manufacturers call ‘Calibration’) is a process of taking where GNSS determines a group of points are at the present time and putting it where you want it to be. This could shift, translate/rotate and/or elevate your coordinates.

You may wish to or be required to constrain a project to published control. Or there is a change in reference framework (datum), or plate velocity or other deformation has moved your point from a previously established set of coordinates.

There may be a horizontal component (that could include both a shift and a rotation), and or a vertical component—very likely both.



A localization could include combinations of translations, rotations, elevation, and adjustments.

This is similar to the concept and process of registering, for instance, aerial photogrammetry and lidar to ground control point (GCP) coordinates.

Scenarios Where You Would Localize

If you are required to use the coordinates of previously published survey control, that vary from recently observed GNSS derived coordinates. This may be due to plate tectonic velocity, a different reference frame, a local reference system, or a custom project datum

Localization and NAD83-2011 to NARFT2022 Modernization

The shift from the NAD83-2011 to NATRF20022 reference frame (datum) will be substantial (e.g. compared to the NSD83-CORS96-toNAD83-2011 shift). Going from the legacy NAD83 (ellipsoid) to the global ellipsoid (as referenced for ITRF2020 and NATRF2022) will result in new coordinates that differ approximately 4.25' (horizontal) and 1' vertical (ellipsoid height), varying slightly across Washington state. The NAPDGD2022 vertical reference will differ from NAVD88 by around 3'.

You may wish to, or be required to, continue existing projects in NAD83-2011 and/or NAVD88 or translate/rotate/elevate the legacy project to NATRF2022 and/or NAPGD2022. Localization is a process that can accommodate this.

Such processes are essential in situations where there is no canned, purely mathematical transformation available. Instead, through the process of localization, you create very precise and localized mathematical relationships.

Types of Newly Derived Coordinates

There are two ways you derive new coordinates, to apply to a localization to legacy coordinates; the first being the most common approach. For example, if you begin working in a new reference frame, like NATRF2022, but wish to localize to a legacy reference frame, like NAD83-2011.

- GNSS-Observed Coordinates
  - You can generate new (now) GNSS-derived coordinates through fresh real-time observations (e.g., RTK, network RTK as with the WSRN), or use geodetic time-dependent tools)
  - You can do new static observations on control points and post-process, to yield new coordinates that are time-stamped for the date of those field sessions
  - You could post-process old observations (with a stated date) in a new reference frame.
- Modeled Coordinates
  - You can take legacy coordinates (noting the reference frame and date of observations) and use geodetic, time-dependent tools (e.g., NGS NCAT/HTDP) to create coordinates on a desired reference frame and date. For example, you

have coordinates from 1998, which were derived with a NAD83CORS96 reference and/or whatever iteration of state plane coordinates system, and use NCAT to give you the estimated NAD83-2011 (and associated SPC projection) coordinates for a date say, in the 2010s, or NATRF2022 (and associated SPC) for a current date. You can even get estimated coordinates for a date in the future (e.g., for when you anticipate a project will start).

  - Your first choice should be reobservation, or reprocessing, because modeled coordinates are just that: *modeled*. The models are derived from velocities observed by NGS CORS stations and there are relatively few of those in WA), and various geodetic transformations.

Field and Office Localizations

- **Field:** Modern survey field (rover) software include localization/calibration routines, that step you through process of entering/importing legacy coordinates, performing the new observations, checking the relative integrity of the published legacy coordinates, and adjusting as needed. With a localization stored and applied, all subsequent processed observations (in a project where a localization has been applied) yield coordinates constrained to the desired reference. You can export a localization and import it into other rovers.
- **Office:** Alternately, you could derive new coordinates and apply those in your survey, CAD, or GIS software. E.g., you could translate and rotate all points and linework in a CAD drawing, and/or change the vertical component (raising or lowering), or both if applicable.
- After the localization, collecting new points outside of the polygon bounding the localization is not recommended.

Workflow

While the workflow may vary between different manufacturers' field and office software, the steps are fundamentally the same.

- Import or input control point coordinates you seek to constrain to.
- Do new observations for each control point. Field software should step you through this step.
- As you make the new observations, the software will indicate the relative integrity between the control points; a 'closure' report of sorts. You can examine the residuals and

decide if the relative integrity meets your precision needs. If you discover an obvious outlier, you have the option of excluding that point or points from the localization. The accepted points will inform an adjustment to create a localization for that project.

- Subsequent points observed, in the project where the accepted localization has been applied, will be transformed to the reference frame of the imported/input original coordinates.
- A full network adjustment (in the office) is recommended for very large projects

Localization Approaches

- **Single point (radial).** In situations where you may only have a single legacy control point, or for a very small project area, a single point localization may suffice. However, in larger project areas, the variations in the geoid model could affect the results. The single point may be used for both horizontal and vertical localization. *See Figure 1*
- **Multi-point horizontal localization.** Optimally, 5+ (well distributed) control points should be used, with, for instance, 4 points outside of the project area and one or more inside. You may not have that many legacy control points available to constrain to. While less can work, depending on the size of the project area, this can weaken the least squares adjustment. See *Figure 2*
- **Multi-point vertical localization.** Optimally, 4 (well distributed) points, with some outside of the project area, should be used. This provides proper least squares fit. One could suffice, but with two, you get a “two-legged stool” situation. While 3 is better, 4 is optimal. *See Figure 3*
- **Multi-point mixed horizontal and vertical localization.** *See Figure 4*
- **Multi-point combined horizontal and vertical localization.** *See Figure 5*

Mixing points from different sources is not recommended. This can introduce additional error. Using points tied to the National Spatial Reference System (e.g., NGS marks and benchmarks, or WSDOT control) is recommended.

Or, if the legacy control was established, observed and processed at the same time, with consistent methods and quality, mixing points from different sources could work. For example, if you established control for a project as one control point campaign.

There may be few suitable control points. You work with what you can, but be aware that for larger projects, this might cause more errors. Check the residuals. Control with limited sky view and potential multi-path hazards might also introduce additional error and imprecision. In such environments, be sure to use field methods like multiple observations and breaking lock in between, to check precision and repeatability.

You may have established project control coordinates on an assumed basis, or a modified state plane “project datum” (e.g., a WSDOT project datum). This can still work if the relative precision between points is consistent. You may have an array of control points where grid-to-ground (e.g., combined grid factor) has been applied. Unless the project is very large, the adjustment component of the localization routine will account for this.

You can use a test to check the localization. Daily check-ins on control is a good best practice, localized or not. Take test shots on control after the localization has been applied to see how it fits. You could use a total station and/or level to establish additional test points. Compare inverses between points.

Software Specifics

Again, consult with your software manual, or vendor to see how they have implemented localization/calibration routines.

Figures

Figure 1 – Single control point (radial). Suitable only for small project sites.

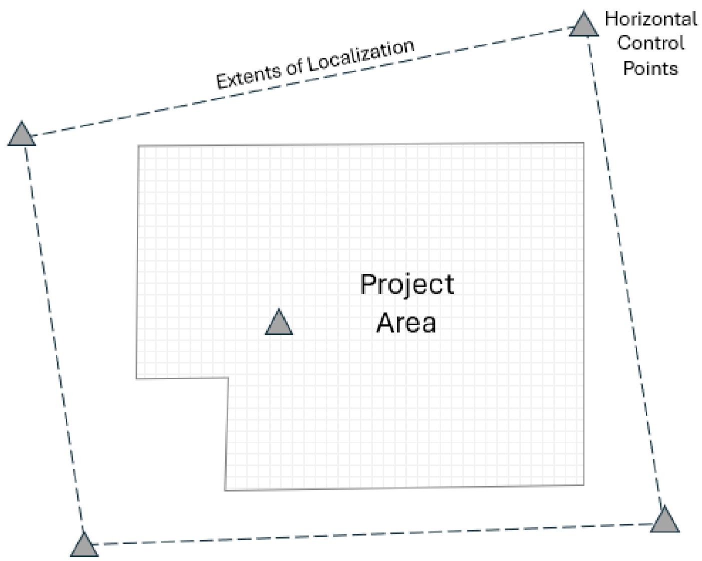


Figure 2 – Multi-point horizontal control

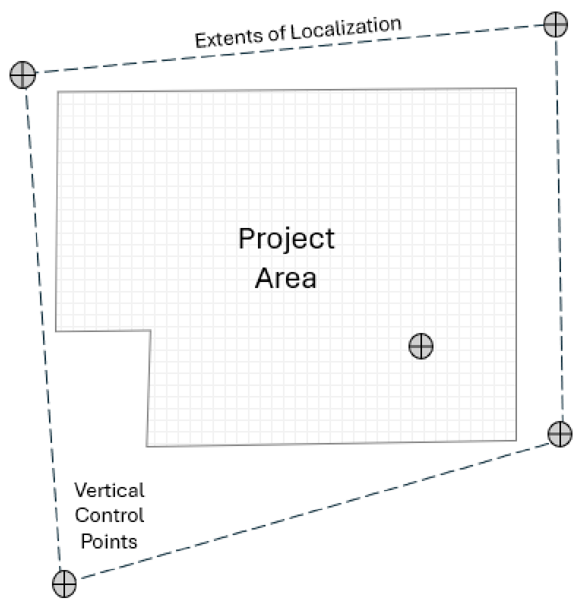


Figure 3 – Multi-point vertical control

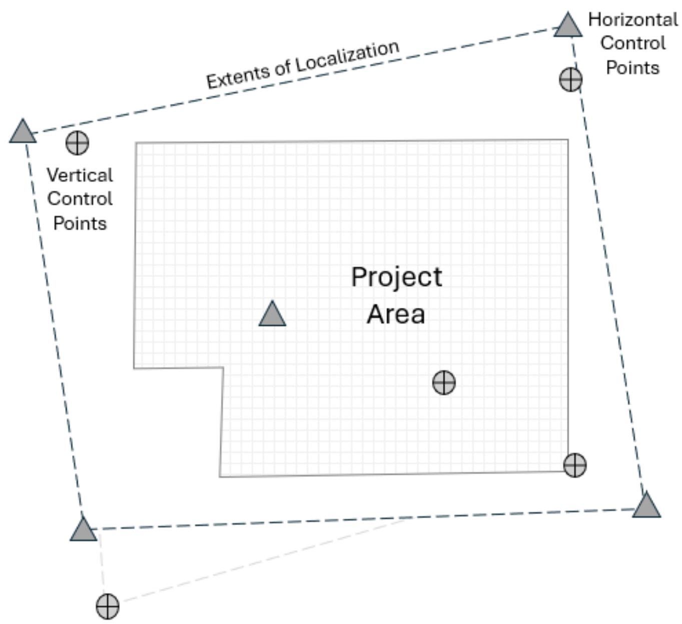


Figure 4 – Multi-point mixed horizontal and vertical control. Note that the effective area is only where the horizontal and vertical extents overlap

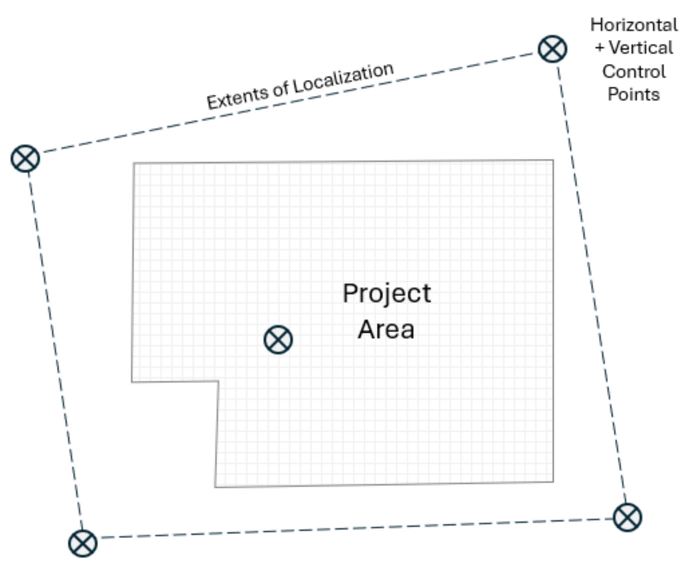


Figure 5 – Multi-point horizontal+vertical control