NavView User Guide – 06 Calculations

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Contents

6. Calculations

This section provides an overview of how calculations are created and configured.

6.1 Overview

The term *Calculations* refers to the application of select observations in a specific algorithm to generate a new set of observations. The resulting observations from a calculation can be used in the same way as any other observation, e.g. as input to another calculation, application to a vehicle for positioning, monitoring via time series window, output to another system, etc., depending upon the requirements.

This section details the calculation types, how they are managed including adding, removing, configuring, applying and monitoring.

Note: If Roles are enabled, only users with Administrator privileges can add, edit or remove calculations.

6.2 Calculation Types

The following lists the Calculation types NavView supports and their basic application:

- Rigid Body Calculation
  - Provides a body state and associated observations that can be used to position objects/vehicles
- Kalman Filter Calculation
  - Provides a horizontal Kalman filtered body state and associated observations that can be used to position objects/vehicles
- Static Draft Calculation
  - Provides an elevation observation using draft and pitch/roll data that can be used as input to another calculation, e.g. Rigid Body, where elevation is important for associated processing such as anchor catenary modelling
- Seabed Elevation Calculation
  - Provides an elevation observation based on a body data source elevation, e.g. an ROV Vehicle or Calculation, and an Altitude sensor
- Relative Lever Arm Calculation
  - Calculates the lever arm for selected position and elevation data sources based on a reference body, e.g. use a known DGPS derived vehicle position to check another DGPS antenna lever arm
- Predicted Position
  - Provides the position and heading predicted ahead using operator configured time
- Depth From Pressure Calculation

- Provides an elevation observation from pressure data that can be used as input to another calculation, e.g. where this is used as the depth of a vehicle, or logged to be used with sound velocity data to generate sound velocity profiles

- Generic Calculation
  - Create observations by applying basic mathematical equations to multiple data source observations, e.g. add a Tilt Direction derived from pitch and roll to a Reference Heading to determine the Tilt Azimuth
- Heading From Positions Calculation
  - Provides a heading observation that can be used as input to another calculation
- Lookup
  - Returns a value in a CSV Table an example would be a Layback based on a Station or KP of lay vessel
- DTM Elevation Calculation
  - Provides an elevation observation from the DTM based on a position observation data source
- Relative Position (Dynamic Body) Calculation
  - Relative position calculations of remote targets using observations from a total station mounted on a dynamic body (e.g. Vessel)
- Rigid Transform (Local) Calculation
  - The Rigid Transform (Local) calculation will determine the best-fitting rigid transformation that aligns two sets of corresponding points in a local framework to provide a position, applicable to precise relative positioning between a static and dynamic object using the results of a Relative Position (Dynamic Body) Calculation
- Rigid Transform (Geographic) Calculation
  - The Rigid Transform (Geographic) calculation takes geographic coordinates from one body and transforms them to another to provide a position
- Relative Position (Static) Calculation
  - Relative position calculations of remote targets using observations from a total station mounted on a static object (e.g. on land)
- Angular Acceleration Algorithm Calculation
  - Provides an angular acceleration observation for input to another calculation, e.g. Remote Motion Algorithm, when this observation is not available directly from a sensor
- Remote Motion Algorithm Calculation
  - Provides linear velocity and acceleration observations and a heave observations for monitoring heave and/or motion at any given static or dynamic point associated with a vehicle

6.3 Error Propagation

Calculations propagate the position error from device input to calculation output. Where applicable, the configuration of devices includes the option to enter standard deviations for the observations they publish, or alternatively the standard deviations or accuracies included in the device input can be used. Entry of offsets, whether at the device, calculation or vehicle level, also include the option to enter standard deviations for each component. As a result, NavView is able to perform rigorous error propagation incorporating not just the input data accuracy but also the accuracy of the translation to the respective final locations.

The resulting error ellipse data is available for display and monitoring with the vehicle the respective calculation is associated with. This includes a graphical representation in the Map view.

6.4 Managing Calculations

Calculations are managed from the Configure Calculations dialog. This can be accessed from the Setup ribbon by clicking on Calculations in the Configure section (see Figure 6-1).

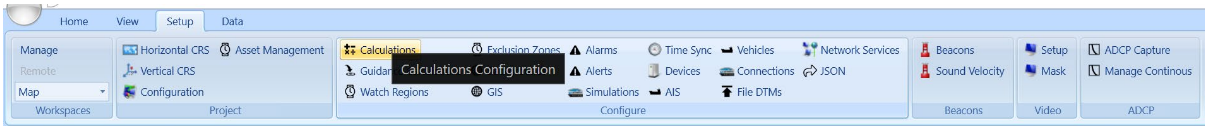


FIGURE 6-1 CALCULATIONS - SETUP RIBBON

Alternatively, Calculations can be managed from the project Explorer view by selecting Calculations under the Setup branch.

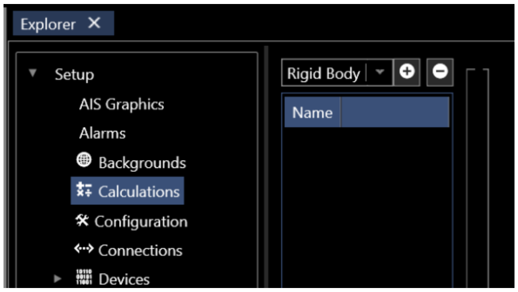


FIGURE 6-2 CALCULATIONS - EXPLORER

6.4.1 Add a Calculation

A calculation can be added from the Configure Calculations views (see Figure 6-2) or directly from a Vehicle configuration. Once added, it can be configured. The configuration can also be done and/or edited later.

6.4.1.1 Add a Calculation from the Configure Calculations View

1. Access the Configure Calculations view from the Setup Ribbon or the project Explorer view.

2. Click the drop-down list and select the calculation type to add.

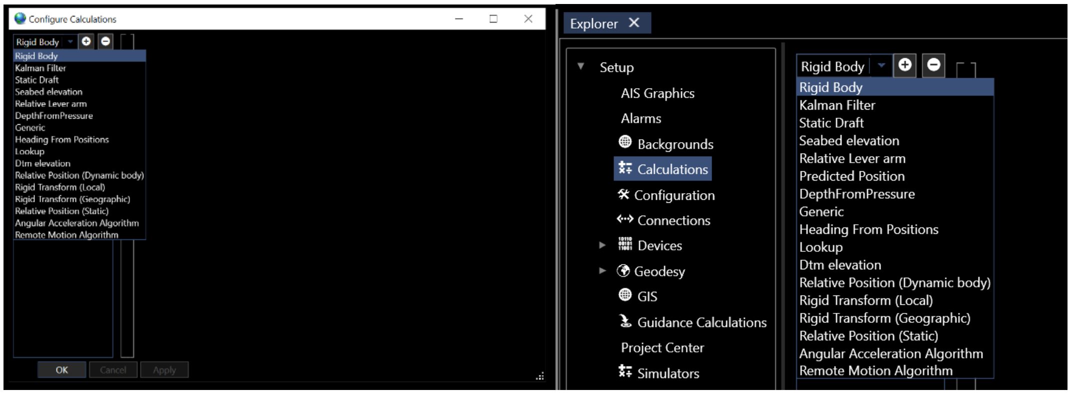


FIGURE 6-3 ADDING A CALCULATION

3. Click the button

6.4.1.2 Add a Calculation from a Vehicle

A Calculation that provides a Body State can be created directly from the vehicle configuration.

1. Access the Vehicle configuration, either via the Add Vehicle wizard or the Configure Vehicle view (see Vehicles section)

2. Click the CRP Position drop-down list and click on **Add new Rigid Body calculation...** or **Add new Kalman Filter calculation...**

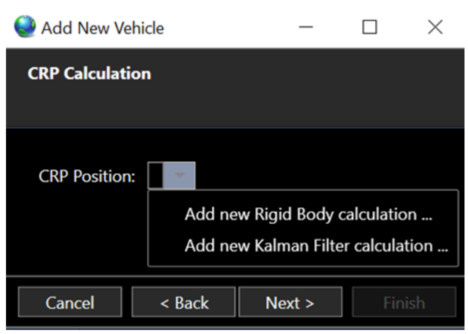


FIGURE 6-4 ADD A CALCULATION VIA VEHICLE CONFIGURATION

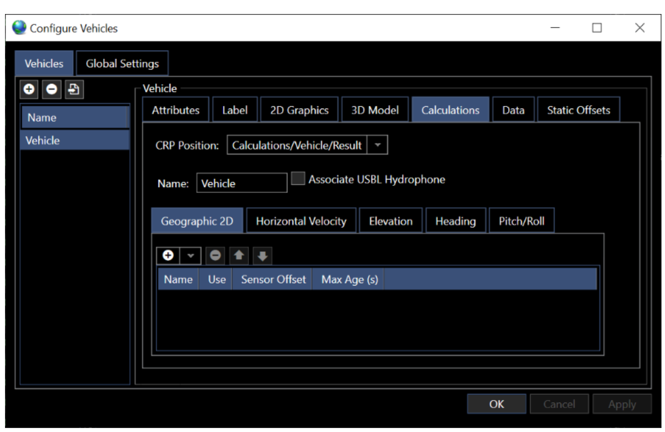


FIGURE 6-5 CALCULATION ADDED VIA VEHICLE CONFIGURATION

6.4.2 Remove a Calculation

1. Access the Configure Calculation view from the Setup Ribbon or the project Explorer view.
2. Select the calculation to remove.
3. Click the button.
4. When prompted, answer Yes to continue and remove the calculation or No to abort the process.

6.4.3 Edit a Calculation

A calculation can be configured when it is added. Alternatively, it can be configured and/or edited at a later time. The steps to follow to access the calculation configuration are given here. The specific configuration is dependent upon the type of calculation and is detailed later in this section.

1. Access the Configure Calculation window
   a. Click on Calculations in the Setup Ribbon.
   b. Select the Calculation to edit.

or

   c. In the project Explorer window, expand the Calculations branch.
   d. Select the Calculation to edit/

or

   e. Click on Vehicles in the Setup Ribbon to open the Configure Vehicles window
   f. Select the Vehicle with which the calculation to edit is associated.
   g. Select Calculations tab.

or

   h. From the Explorer window, expand the vehicles branch.
   i. Expand the branch for the Vehicle with which the calculation to edit is associated.
   j. Select Calculations branch.

then

2. Edit the calculation.
3. Click the Apply button.

Note: When a change is made in the Configure Calculations dialog, the Apply and Cancel buttons will become active.

- Click the Apply button to apply the changes. The changes will not be applied if the dialog is closed without applying first

- Click the Cancel button to revert all changes made since the last time the Apply button was clicked
- Click the OK button to close the dialog

6.5 Configuring Calculation Input Observations

All calculations require the assignment and configuration of input observations. For most calculations, this involves selecting one or more of the appropriate observation sources and configuring their relationship with the CRP.

In the case of the Rigid Body, Kalman Filter and Static Draft (for the Pitch/Roll observations) calculations, multiple observations(Devices) for any one type can be added but only one of these is used for the calculation, the rest are available for monitoring and use in the case the used observation source fails, see Automatic Failover. For these calculations, the configuration also includes organizing the sequence of the observations in the calculation and configuring their use and failover state.

These calculations present a common user interface for this. This section details the managing and configuring of the input observations applicable to these Calculations. Those that do not follow this approach are detailed in the respective section.

This example uses a Rigid Body calculation.

1. To Add an observation source:
   a. Click the tab to select the observation type to be configured (e.g. Geographic 2D, Horizontal Velocity, Elevation, Altitude, Heading or Pitch/Roll)
   b. Click on the [▾] in the [⊕ ▾] button to display a hierarchical list of the available respective observation sources

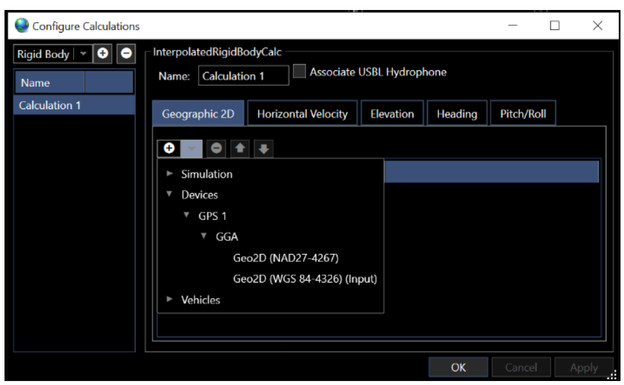


FIGURE 6-6 ADDING AN OBSERVATION

   c. Navigate to and select the desired observation source to add it to the data grid
   d. Repeat these steps to add all required observation sources for a specific observation type

Note: Once an observation is added to a calculation, it will no longer appear in the respective list of available observations for that calculation. It is still available for adding to other calculations.

Note: The Elevation and Pitch/Roll observations' options include **Fixed** which enable the user to assign a fixed value for these data to be applied in the calculation. In the case of the Elevation observation this can be used to ensure the correct relationship of a calculation and therefore a vehicle to the water surface for correct representation in the 3D View.

Note: The Heading observation's options include **Fixed** which enables the user to assign a fixed heading value to the calculation, and **CMG** which uses the Course Made Good (CMG) as determined from the Geographic 2D data as the heading. Since heading is required for a calculation to be considered to be valid and useable, it is recommended that this be considered only as the final option for the failover feature.

2. To Remove an observation source:
   a. Click the tab to select the observation type to be removed
   b. Select the observation to be removed in the data grid
   c. Click the ⊖ button

3. To move an observation's place in the list, i.e. change the failover order:
   a. Click the tab to select the observation type to be configured
   b. Select the observation to be moved in the data grid
   c. Click the ⇧ or ⇩ button to move the observation down or up one spot

Note: The order the observations appear in the data grid are critical where the automatic failover is used, as this dictates the order they are used in the case of one or more failing.

4. Once added to the calculation, each observation, whose options are comprised of some combination of the following depending on the type, is configured by direct editing of the cells in the data grid:
   a. **Use**: Controls the use of the observation in the calculation
      i. If this observation is to be used for the calculation, either as the sole observation to be used, or as one of several to be used with the failover feature, check the Use box (default)
      ii. If this observation is not to be used in the calculation but to be included so it can be monitored against those that are used, uncheck this box
   b. **Sensor Offset**: These offsets relate the source to the calculation's CRP, click in this cell to expand it to enable editing of the offsets and their standard deviations (optional for error propagation)

Note: Offsets are *From* the CRP *To* the Sensor where

X: - is to port; + is to starboard

Y: - is to the stern; + is to the bow

Z: - is down; + is up

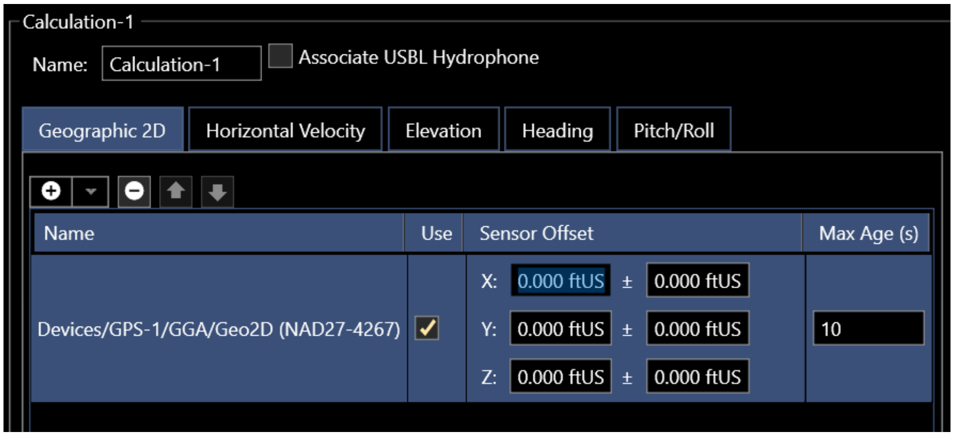


FIGURE 6-7 SENSOR OFFSETS ENTRY

Note: The sensor offset units default to the Preference Distance setting units. Offsets can be entered using other units by adding the respective indicator, e.g. "m" after the value.

Note: Sensor offsets are only available for configuration for those observations they are applicable to, i.e. Geographic 2D and Elevation.

c. **Max Age**: Enter the age at which this observation data is considered to have failed thus triggering either a failover (if multiple observations are present and set to Use) or simply the cessation of this data input to the calculation

Note: In the case of the Geographic 2D or Heading observation, the cessation of either of these observation types updating the calculation will result in the calculation to fail.

d. **C-O:** Some observations will have a cell to enter the Calculated minus Observed correction for the observation, this value is added to the observed data before it is used

Note: The C-O is a correction to the sensor data and is applied before any other processing is performed on the data, e.g. before applying offsets or attitude corrections.

Note: C-O corrections are only available for configuration for those observations they are applicable to, i.e. Elevation, Heading and Pitch/Roll.

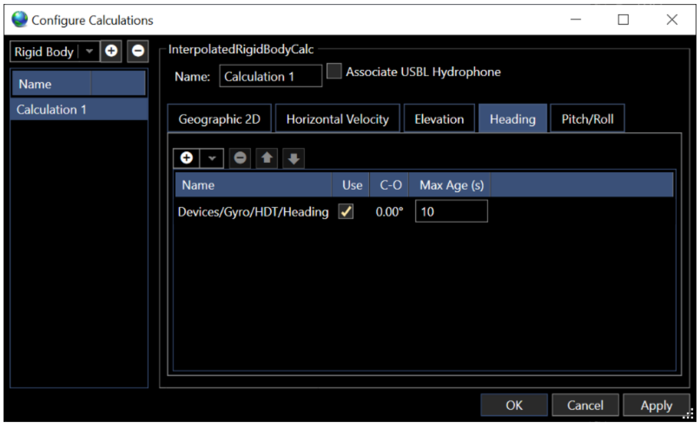


FIGURE 6-8 SENSOR C-O ENTRY

5. Repeat the Add process for all required observations for the calculation.

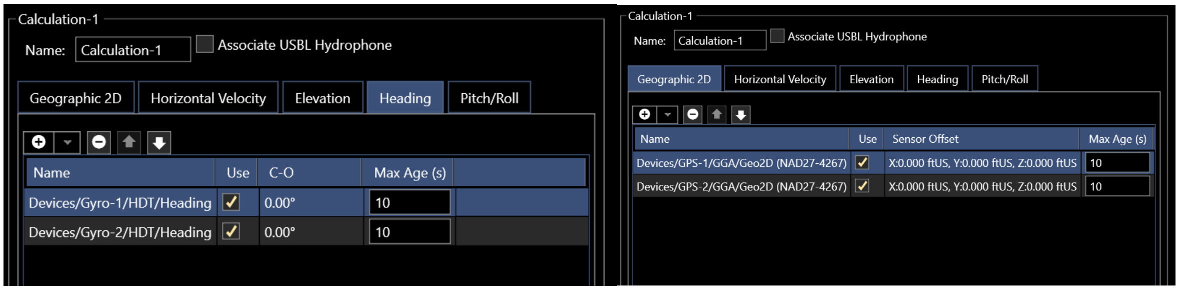


FIGURE 6-9 EXAMPLES OF OBSERVATIONS ADDED TO RIGID BODY CALCULATION

6.6 Automatic Failover

Select calculations (Rigid Body, Kalman Filter and Static Draft) support multiple observations of any one type to be added to the calculation. However, only one is actually applied to the calculation. Which one is used is controlled by a combination of the Use flag and the order the observations appear in the respective data grid.

If multiple observations of one type are added but only one has its Use box checked, this is the only one that will be used for the calculation. Should this observation source fail, the calculation will stop updating.

If multiple observations of one type are added and more than one has its Use box checked, NavView's automatic failover feature is activated. In this case it is important that the observations be organized in the order they are to be used in the case of failure of any one or combination of them. Each source is configured to be used or not used in the switchover process by checking or unchecking their Use box, and if to be used, how long after a source is deemed to not be providing acceptable data, i.e. fails for the length of time set as its Max Age, is the switch to the next source in the list to take place. When a source that has failed recovers, it is reverted to as the source for that observation type to the calculation.

Note: The term Fail refers to unacceptable data being published by the respective source. This may be based on one or more of the following:

- The device or the respective interface has failed and is no longer providing data to NavView
- Messages are being received but are failing validation
- Messages are being received but failing operator configured minimum tolerances for use, e.g. GPS position is single point and not differentially corrected

The failover list of observation sources is unlimited in the number that can be added. When a source fails, NavView switches to the next in the list that is currently providing acceptable data. If no source is providing acceptable data, the calculation fails. As each source recovers and starts to provide acceptable data again, NavView switches to the one highest in the list as the source to provide data to the calculation.

6.7 Rigid Body Calculation

The Rigid Body calculation is a general position solution for a CRP that incorporates the following observation types.

- Geographic 2D
- Horizontal Velocity
- Elevation
- Heading
- Pitch/Roll

When any of the aforementioned observations associated with the calculation is updated by the respective source, it is added to a fading history of that observation maintained by the calculation. When a Geographic 2D observation update is received, the fading histories for the other observation types are used to interpolate, or extrapolate depending on the available data, the respective values for the Geographic 2D observation epoch. The calculation then publishes a Body State and the following observation types for this epoch.

- Geographic 2D
- Horizontal Velocity
- Elevation
- Heading
- Pitch/Roll

Note: The Rigid Body calculation at a minimum requires a Geographic 2D observation and heading data, the latter either as a Heading observation or set to Fixed or CMG, in order to publish any observations, i.e. update any users of the calculation. If an Elevation observation and/or a Pitch/Roll observation are available, they will be used and published accordingly but they are not necessary.

Note: The observation published by a Rigid Body calculation can be used as observation sources for other calculations.

6.7.1 Multiple Observation Sources and Automatic Failover

Only one observation source of each type is used in the Rigid Body calculation. However, multiples of any type can be added, monitored and configured for Automatic Failover (see Automatic Failover).

6.7.2 Horizontal Velocity

The Rigid Body calculation calculates a smoothed horizontal velocity (speed) based on the Geographic 2D position updates. It also supports the adding of Horizontal Velocity observation sources to the calculation, e.g. from NMEA VTG messages. The operator has the option to specify if the calculated Horizontal Velocity value is published with the Body State or if the fading history of Horizontal Velocity observations added to the calculation is used to provide the value published with the Body State.

6.7.3 Configure the Rigid Body Calculation

The configuring of a Rigid Body calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Rigid Body calculation to be configured (see Edit a Calculation).

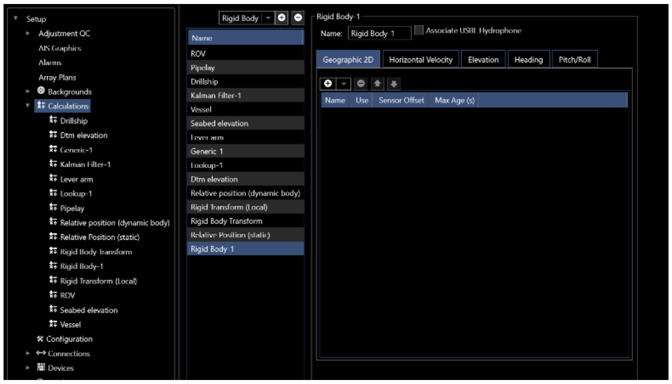


FIGURE 6-10 RIGID BODY CONFIGURATION

2. **Name**: Enter a name for the calculation, it is recommended that the name be kept short but still indicative of the calculation sources and/or purpose.
3. **Associate USBL Hydrophone**: See USBL
4. Configure the observations as required (see Configuring Calculation Input Observations)
5. Click Apply (if present, dependent upon the view used)

6.7.4 Monitoring the Rigid Body Calculation

The Rigid Body calculation is monitored with the Calculation window. This is opened from the View ribbon by clicking on the Calculations button in the Windows section.

FIGURE 6-11 CALCULATIONS VIEW – VIEW RIBBON

The Calculations window displays the current calculations in the left panel in a tree that can be expanded to display the associated observations and their sources. The status of the calculations and their observations are indicated by ✅ (good) and ❌ (bad).

The right panel displays details for the selection made in the left panel. If a Rigid Body calculation is selected, all observations associated with the calculation are displayed (see Figure 6-12). If a specific observation type is selected, just the observations of that type are displayed (see Figure 6-13). If a specific observation is selected, the right panel does not display anything.

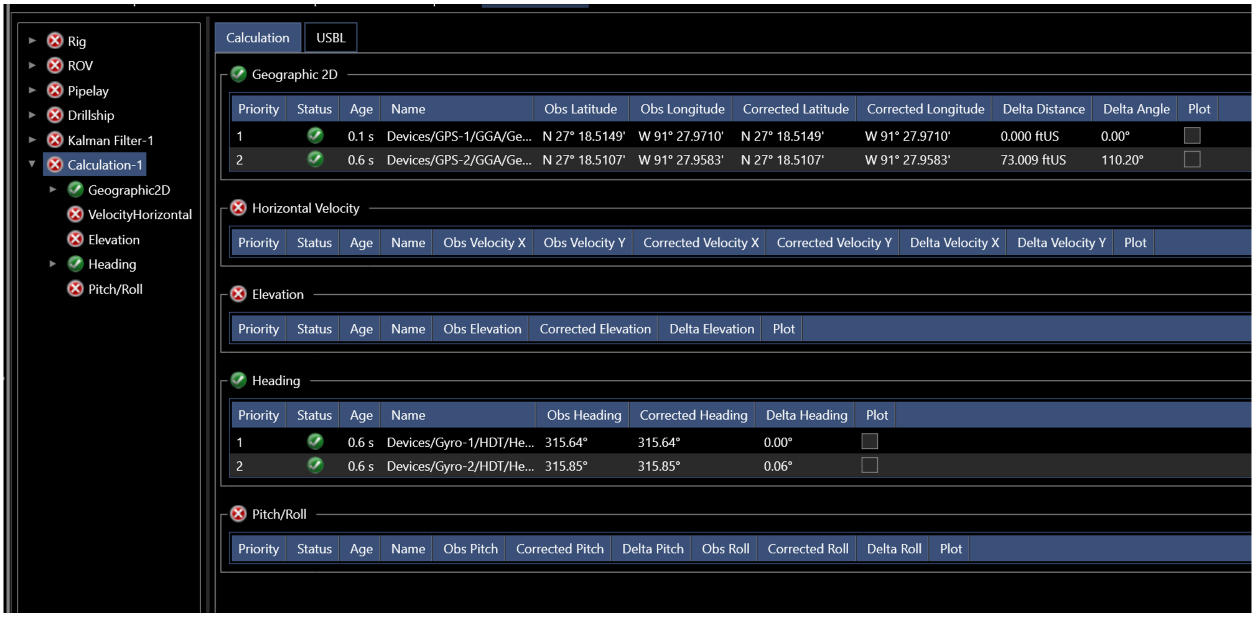


FIGURE 6-12 CALCULATIONS WINDOW - RIGID BODY CALCULATION - ALL DATA SOURCES DISPLAYED

Calculations right panel details include the following:

- Priority
  - The priority assigned as per the order within a multi-observation source list.
- Status:
  - ✅ if the data is valid and not timed out, ❌ if the data is not valid or has timed out.
- Age:
  - Age of the current data.
- Name:
  - Names assigned by the operator for the observation source.
- Obs(s):
  - Raw observation, i.e. not translated for offsets. Where (*s*) is the data type.

Note: The number of Obs columns correspond to the number data items associated with the observation type, e.g. a Geographic2D observation has latitude and longitude whereas Heading has just heading.

- Corrected(*s*):
  - Corrected observation, e.g. translated to the CRP or C-O applied.
  - The number of columns corresponds to the number of data items associated with the observation type.
- Delta(*s*):
  - The variation of corrected observation types of priority 2 and lower compared to priority 1.

- The number of columns corresponds to the number of data items associated with the observation type.
- Plot:
  - Check this box to generate a time series plot of the associated observation.
  - To view plot, select the observation type in the left panel of the calculations window.

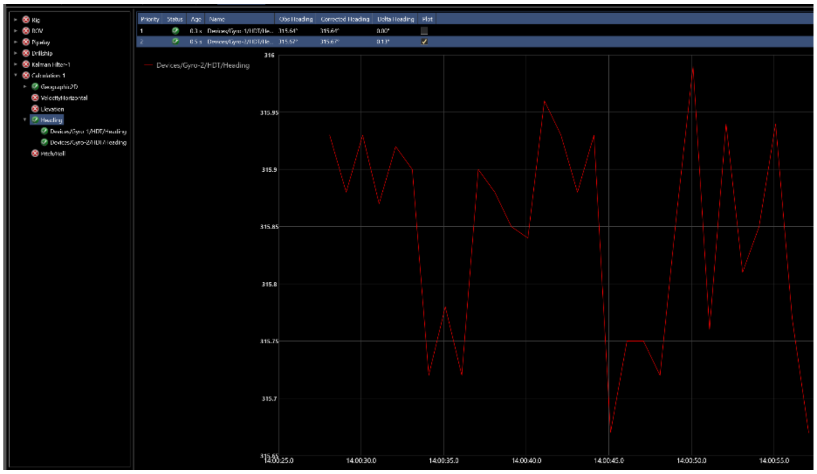


FIGURE 6-13 CALCULATIONS WINDOW - RIGID BODY CALCULATION – HEADING DATA WITH PLOT

6.8 USBL Calculation

The method for applying USBL data for positioning surface, subsea vehicles and objects depends upon the data being provided by the USBL system, position or Cartesian data, and in the case of the latter, the USBL system's reference point. The basic process is as follows:

1. Data is received at the USBL device.

2. Is the data Position/Depth?
   a. Yes:
      i. Identify the beacon associated with the data.
      ii. Publish the Geographic2D and Elevation observations on the beacon's data source.
      iii. Go to 5
   b. No: Go to 3

3. Is the data Cartesian (XYZ)?
   a. Yes:
      i. Is the data relative to the ship's bow?
         A. Yes:
            I. Apply USBL system offsets to translate XYZ data to the transducer.
            II. Apply USBL calibration corrections.
            III. Publish USBL observations.
      ii. No:

I. Publish USBL observations.

iii. Go to 4

b. No:
   i. No further processing

4. When the Rigid Body calculation that has been created for the vehicle to which the USBL transducer is attached, and the USBL observation data source has been assigned receives USBL observations.
   a. Identify the beacon associated with the data.
   b. Interpolate/extrapolate a Rigid Body CRP position, elevation, heading, pitch and roll for the USBL data epoch.
   c. Apply NavView sensor offsets to translate this CRP position and elevation to the point the USBL data is relative to.
   d. Apply the USBL observations to determine position and elevation of the beacon.
   e. Publish the Geographic2D and Elevation observations on the beacon's data source.
   f. Go to 5

5. Assign beacon Geographic2D and Elevation observations to the calculation to be used for the vehicle the beacon is associated with.

The following sections provides details for using USBL data.

6.8.1 Beacon Data Sources

USBL beacons are identified by a channel, also referred to as an ID. Data received from a USBL system includes the ID of the beacon the data is for. When NavView processes the USBL data it looks for a beacon with the same ID in the NavView beacon file and if found, publishes the resulting Geographic2D and Elevation observations on that beacon's data source. If a match is not found, a record that a match cannot be found is written to the log file and no observations are published for that beacon. Therefore, all beacons that are to be used by NavView must be added to the NavView Beacon file (see Acoustics).

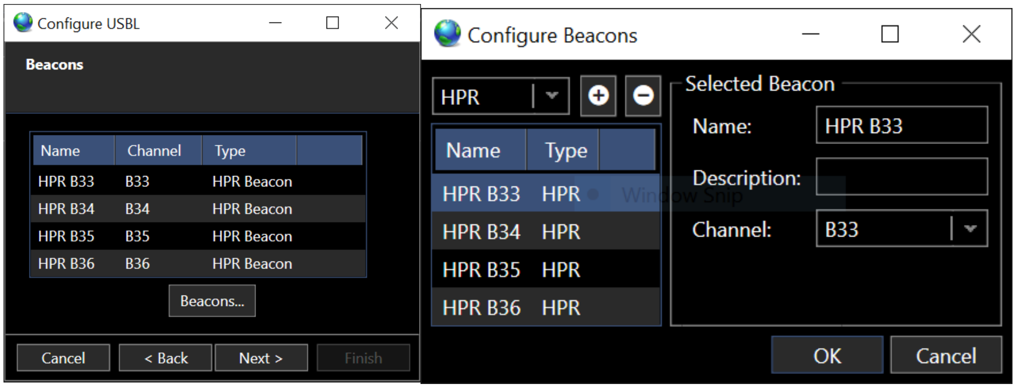


FIGURE 6-14 NAVVIEW BEACONS

It is important to note that USBL systems can also output data for the vessel that the USBL hydrophone is mounted on. In this case, a beacon with the respective ID assigned as its channel must be added to the beacon file even though it is not an actual beacon. This enables the required matching so the respective Geographic2D and Elevation observations can be published.

In hierarchical lists of data sources, the beacon data sources are listed under Beacons as shown in Figure 6-15 Beacon Data Sources.

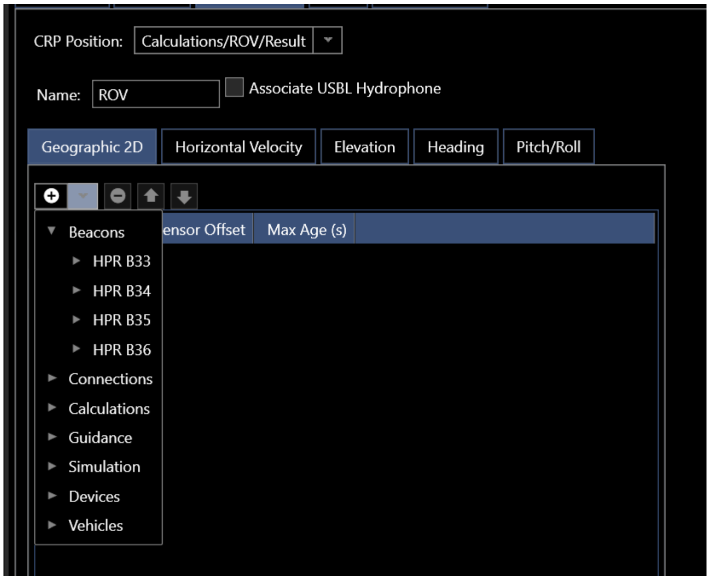


FIGURE 6-15 BEACON DATA SOURCES

See the Acoustics section for details regarding the managing of Beacon files.

6.8.2 Using USBL Position Data

USBL systems can be interfaced with gyros and GPS units enabling them to calculate and output beacon position and depth. Upon receipt of this data at the device level, NavView looks for a match in its beacon file and if found, publishes the Geographic2D and Elevation observations on that beacon's data source directly.

USBL systems can also use seafloor LBL arrays to determine the position of beacons or the USBL hydrophone itself. The data output may be beacon position and depth in which case upon receipt of this data at the device level, NavView looks for a match in its beacon file and if found, the device publishes the Geographic2D and Elevation observations on that beacon's data source directly. Alternatively, the output may be a position relative to the center of the LBL array. In this case, upon receipt of this data at the device level, NavView looks for a match in its beacon file and if found, translates the relational data from the known LBL array center to a position and then proceeds to publish the Geographic2D and Elevation observations on that beacon's data source directly.

These published Geographic 2D and Elevation observations are available for use as any other similar observations published by devices are, including being selectable for Rigid Body and Kalman Filter calculations.

No USBL specific calculation configuration or processing is required by NavView to handle USBL position data.

6.8.3 Using USBL Cartesian Data

USBL systems can also be configured to output Cartesian coordinates, XYZ distances from the USBL system's reference point to the beacon. These may be ship referenced (relative to the vessel's bow) or earth referenced (relative to True north). In either case, the device publishes the following USBL observations:

- USBL
  - These are translated to the USBL transducer and have the USBL calibration corrections applied.
  - These are assigned to a Rigid Body or Kalman Filter calculation to position the associated beacon.
- USBL-RAW (Calibration) (see the Acoustics section)
  - These are the raw untranslated and uncorrected USBL cartesian data as received from the device.
  - These are only assigned to a USBL Calibration as the USBL data source.

USBL observations are assigned to the Rigid Body calculation that is configured for the vehicle that the USBL transducer pole (also referred to as the hydrophone) is mounted on. When this calculation receives the observations, it looks for a match in the NavView beacon file. If found it translates the XYZ data to a beacon position and depth which are published as Geographic 2D and Elevation observations on that beacon's data source. These published Geographic 2D and Elevation observations are available for use as any other observations are, including being selectable for Rigid Body and Kalman Filter calculations.

NavView requires a specific configuration of the Rigid Body calculation for handling USBL Cartesian data. This section details this configuration.

6.8.3.1 Configure the Rigid Body Calculation for a USBL Hydrophone

When using USBL XYZ Cartesian data, NavView requires that a Rigid Body calculation be configured specifically for the vehicle the USBL hydrophone is mounted on. The USBL hydrophone is then associated with this calculation enabling assigning of USBL observation data source(s) to the calculation. Thus, a surface position can be associated with the USBL data to determine beacon positions.

The configuring of a Rigid Body calculation for USBL can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Rigid Body calculation that has been created to position the vessel that the USBL transducer pole is mounted on (see Edit a Calculation)
2. Complete standard configuration of calculation (see Configuring Calculation Input Observations)

3. Check the Associate USBL Hydrophone box, this will result in a USBL tab being added (see Figure 6-16)

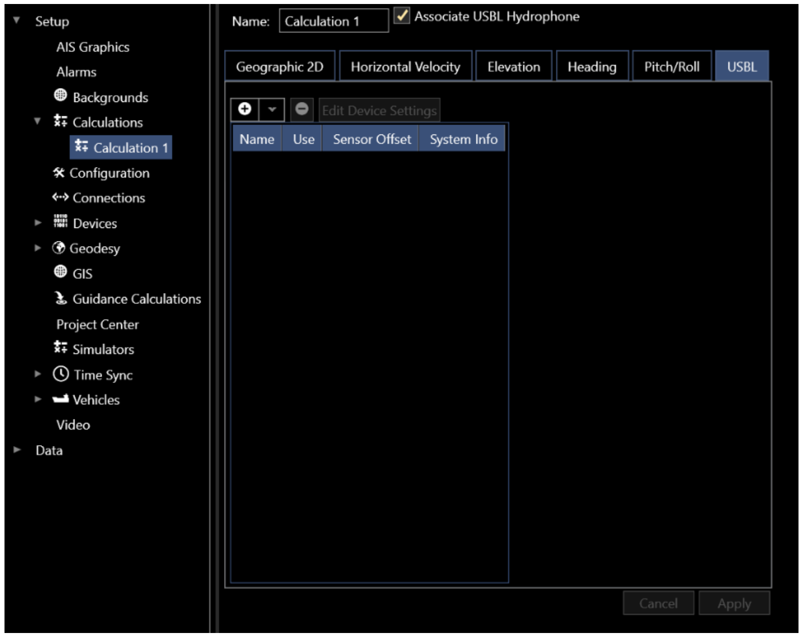


FIGURE 6-16 RIGID BODY CALCULATION - USBL HYDROPHONE OPTION

4. Select the USBL tab.

5. Click on the  in the  button to display a list of the available USBL observation data sources, select the one to use.

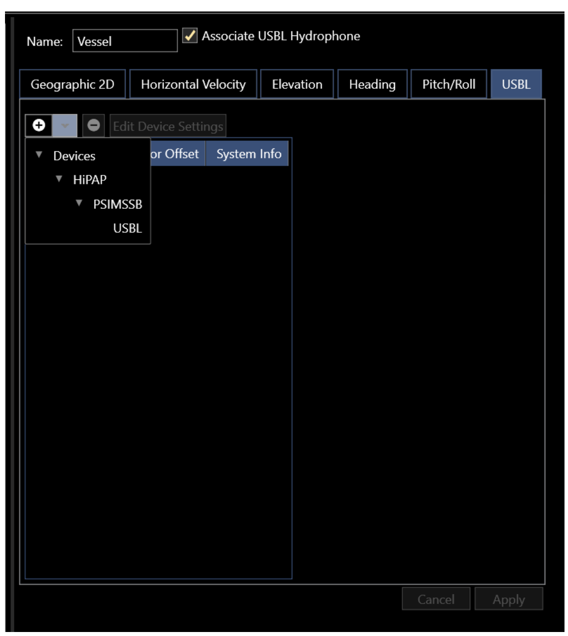


FIGURE 6-17 RIGID BODY CALCULATION - USBL SELECTION

Note: Multiple USBL observation data sources can be added. In this way, vessels with multiple USBL systems can be setup in NavView so the one in use is automatically used.

Note: Assign a USBL data source to a Rigid Body Calculation, **never** a Usbl-RAW data source.

Note: Dual pole systems are not supported.

a. **Use**: Check if the USBL source is to be used
b. **Sensor Offset:** Enter the offsets from the CRP to the USBL sensor, see USBL Offsets for details regarding configuring these
c. **System Info**: This cell displays the configuration for the USBL device. Unlike other configuration items, these cannot be edited directly in the cell as they are associated with the observation source device, see USBL Offsets for details regarding configuring these
d. **Edit device Settings:** Click this button to access the respective device's configuration

6. Click Apply (if present, dependent upon the view used)

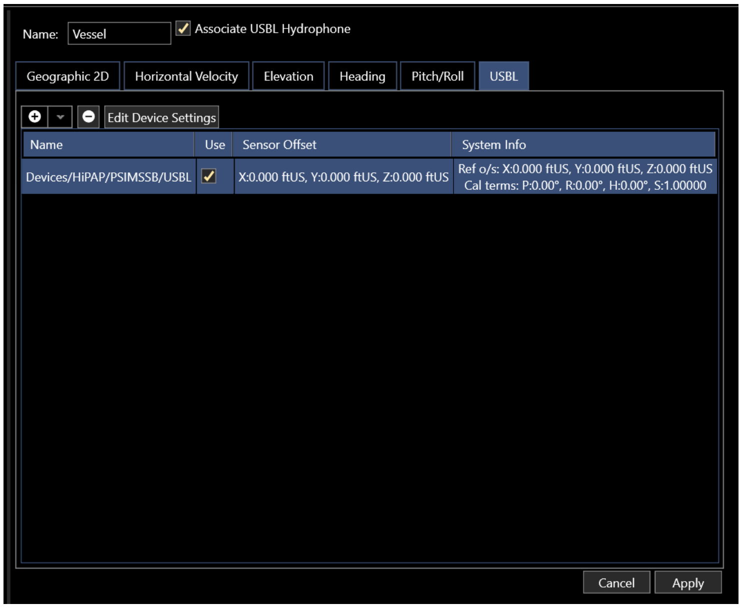


FIGURE 6-18 RIGID BODY CALCULATION – USBL TAB

6.8.3.2 USBL Offsets

In order to correctly configure NavView to process USBL Cartesian data, it is important to understand the offsets involved. These include those entered in the USBL system and those entered in NavView.

USBL systems support the entry of offsets to define the relationship between the USBL transducer pole and the position on the vessel that the output Cartesian data is referenced to, known as the USBL reference point. This reference point is typically the vessel's center of gravity (COG) because the USBL output will be for the Dynamic Positioning (DP) system which uses the COG as its reference point. The Cartesian coordinate data output by the USBL system is relative to this reference point, not the transducer pole.

In NavView, there are two offset entry points for USBL related offsets, one at the device level and one at the calculation level.

6.8.3.2.1 Device: USBL System Offsets

The offsets at the device level enable the user to enter the offsets that are in the USBL system which in turn enables NavView to translate ship referenced Cartesian coordinates it receives from the USBL system, from the USBL reference point back to the transducer pole.

Note: The USBL system's offsets are required to be entered in NavView if NavView is applying a USBL calibration correction to the USBL data and/or if the NavView vessel CRP is different than the ship reference (COG) as this must be applied to the Cartesian coordinates as they relate to the transducer.

Note: If the USBL output is earth referenced Cartesian coordinates, NavView does not perform a translation of the data to the transducer and the USBL system's offsets entered in NavView can be set to 0.0.

Note: If NavView is not applying the USBL calibration to the USBL data and/or NavView vessel CRP is the same as ships reference there is no benefit to translating the Cartesian coordinates back to the transducer pole so these offsets can be set to 0.0.

6.8.3.2.2 Calculation: USBL Sensor Offsets

The NavView offsets entered at the calculation level relate the sensor to the CRP. In the case of USBL observations, the sensor refers to the point that the USBL observations published by the device are relative to. This may or may not be the hydrophone.

Note: If the USBL device has translated the Cartesian coordinates to the transducer pole, the calculation Sensor Offsets are from the CRP to the transducer pole.

Note: If the USBL device has not translated the Cartesian coordinates to the transducer pole, these offsets are from the CRP to the USBL reference point.

6.8.3.2.3 Case 1: USBL outputs ship referenced Cartesian coordinates and NavView is applying USBL calibration Corrections

1. In the USBL device configuration for USBL System Offsets.
    a. Enter the offsets that are entered in the USBL system using the sign convention of USBL reference point to the transducer (see Figure 6-19)
    b. NavView will
        i. Translate the XYZ data to relate to the transducer
        ii. Apply the USBL calibration corrections
        iii. Identify the beacon from the NavView Beacon list and if found, publish the corrected XYZ values relative to the transducer as Usbl observations for that beacon

Note: NavView will also publish the raw untranslated and uncorrected XYZ values as Usbl-RAW observations for use in USBL Calibration data collection and processing.

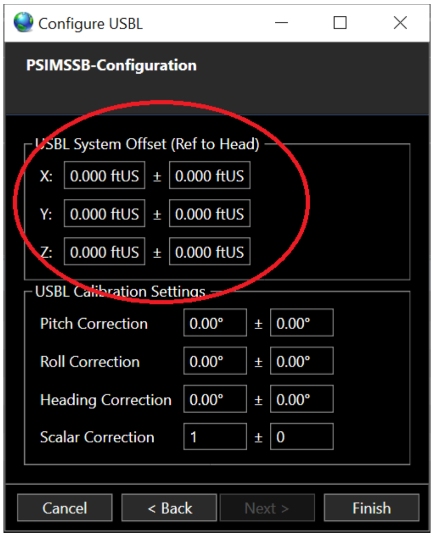


FIGURE 6-19 USBL SYSTEM OFFSETS

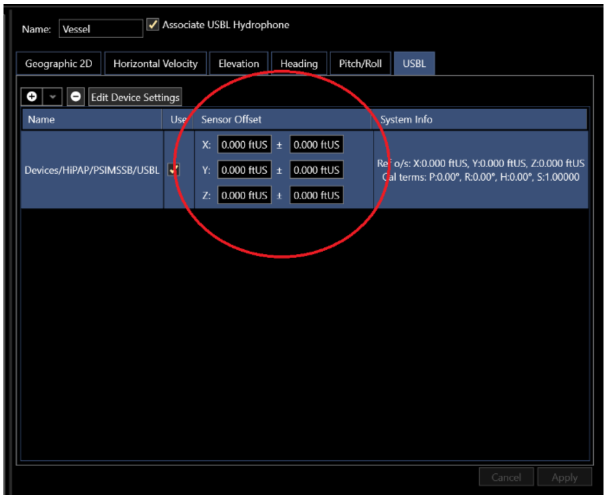


FIGURE 6-20 USBL OBSERVATION SENSOR OFFSETS

2. In the Rigid Body calculation on the USBL tab.
    a. Enter the Sensor Offsets from the CRP to the transducer (see Figure 6-20)
    b. NavView will
        i. Determine a position and depth for the transducer for the USBL data epoch
        ii. Apply the USBL XYZ data, transducer position and depth and vessel heading to calculate a position and depth for the beacon
        iii. Publish the position and depth as observations associated with that beacon

6.8.3.2.4 Case 2: USBL outputs earth referenced Cartesian coordinates or NavView is NOT applying USBL calibration

1. In the USBL device configuration.
    a. Enter 0.0 for the USBL System Offsets (see Figure 6-19)
    b. NavView will

i. Identify the beacon from the NavView Beacon list and if found, publish the XYZ values as received from the device, i.e. relative to the USBL reference point, as USBL observations for that beacon

Note: NavView will also publish these XYZ values as USBL-RAW observations for use in USBL Calibration data collection and processing.

2. In the Rigid Body calculation on the USBL tab.
   a. Enter the Sensor Offsets from the CRP to the USBL reference point (see Figure 6-20)
   b. NavView will
      i. Determine a position and depth for the USBL reference point for the USBL data epoch
      ii. Apply the USBL XYZ data, transducer position and depth and vessel heading to calculate a position and depth for the beacon
      iii. Publish the position and depth as observations associated with that beacon

For details regarding the configuration of the USBL device, see Appendix Device Documents.

6.8.4 Using Beacon Geographic2D and Elevation Observations

The Geographic2D and Elevation observations published on a beacon's data source are available for application in the same as any other similar observations, including being applied to a Rigid Body or Kalman Filter calculation created to position a subsurface vehicle or object. When accessing the hierarchical observation data source list, they are listed under Beacons (see Figure 6-15).

6.9 Kalman Filter Calculation

The Kalman Filter (KF) is an estimation algorithm developed and published by R.E. Kalman in 1960. In NavView, the Kalman Filter calculation is used to create a smoothed position based on various inputs. The KF maintains the state of a vehicle's position and velocity, along with standard deviations of those values. It calculates an estimated position and velocity between actual sensor updates, and the estimates are further refined at subsequent updates.

Like the Rigid Body calculation, the Kalman Filter calculation is a general position solution for the CRP of a vehicle. The Kalman Filter incorporates the following observation types:

- Geographic 2D
- Horizontal Velocity
- Elevation
- Heading
- Pitch/Roll

The Elevation, Heading, and Pitch/Roll observation types are handled as with the Rigid Body Calculation.

The KF maintains an estimate of the position and velocity along with standard deviations, also known as the state. The calculation is updated at a set time interval. At each time update, a new state is estimated based on the previous state. With knowledge of the current position, and the direction in which a body is moving, the algorithm calculates a new position and velocity, with the estimated standard deviations growing with time.

When position or velocity updates are received, they are used to correct the states. The magnitude of the effect of the update on the state is known as the Kalman Gain. This is determined based on the standard deviations of the incoming data vs. the estimated standard deviations of the state. NavView uses the standard deviation of the incoming data in order to bias towards either the position updates, the velocity updates, or the estimated state. For instance, an ROV tracking the seabed could receive relatively rapid and accurate updates of velocity updates from a Doppler Velocity Log system, while at the same time receiving noisy and slower absolute position updates. The KF algorithm will take this data into account to provide a realistic estimate of the body's position and motion, such that it does not move directly towards every position update, but uses the position updates to keep the estimate from drifting from reality.

It is important that the sensor inputs into the Kalman Filter calculation have the correct standard deviations assigned.

The Kalman Filter calculation publishes a Body State and the following observation types at each epoch.

- Geographic 2D
- Horizontal Velocity
- Elevation
- Heading
- Pitch/Roll

6.9.1 Multiple Observation Sources and Automatic Failover

Only one observation source of each type is used in the Kalman Filter calculation. However, multiples of any type can be added, monitored and configured for Automatic Failover (see Automatic Failover).

6.9.2 Configure the Kalman Filter Calculation

The configuring of a Kalman Filter calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Kalman Filter calculation to be configured (see Edit a Calculation)

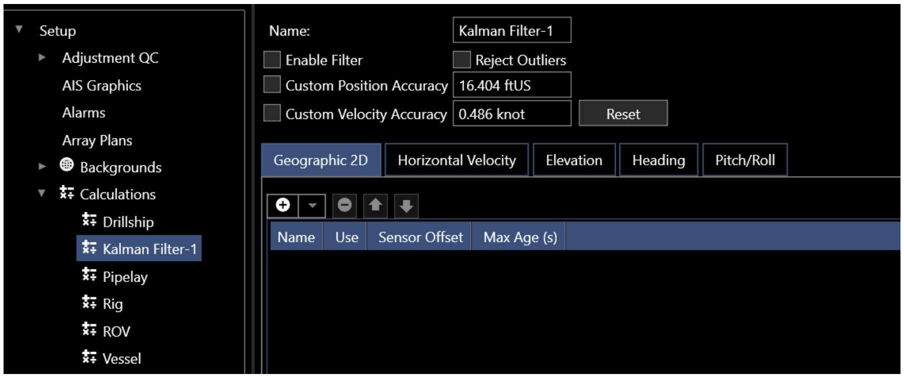


FIGURE 6-21 CONFIGURE KALMAN FILTER CALCULATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Enable Filter:** This enables the user to easily turn on and off the application of the Kalman Filter.
   a. Check this box to activate the Kalman Filter calculation to generate results
   b. Uncheck this box to deactivate the Kalman Filter and generate results as if a Rigid Body calculation

4. **Reject Outliers:** Check this box to reject any data that is outside the Kalman Filter estimate.

5. **Custom Position Accuracy:** Check the box to assign an accuracy to be used by the calculation.

6. **Custom Velocity Accuracy:** Check the box to assign an accuracy to be used by the calculation.

7. **Reset:** Clicking this button resets the Kalman Filter to its default state.

8. Configure the observations as required (see Configuring Calculation Input Observations)

Note: The horizontal velocity observation is used in the Kalman Filter.

Note: The resetting of the Kalman Filter to its default state includes setting the estimated standard deviations to very large values such that any new observations are accepted. This may be used for situations where tracking has just restarted and due to old estimated position in a different location, new observations are being rejected.

9. Click Apply (if present, dependent upon the view used)

6.9.3 Monitoring the Kalman Filter Calculation

The Kalman Filter calculation is monitored with the Calculation window. This is opened from the View ribbon by clicking on the Calculations button in the Windows section.

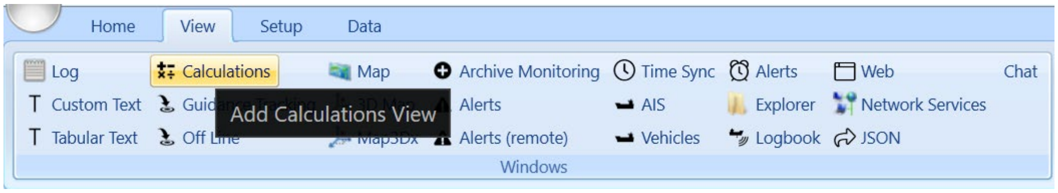


FIGURE 6-22 CALCULATIONS VIEW – VIEW RIBBON

The Calculations window displays the current calculations in the left panel in a tree that can be expanded to display the associated observations and their sources. The right panel displays details for the selection made in the left panel. The various statuses are indicated by (good/accepted) and (bad/old/rejected). The status of the Kalman Filter calculation will be if one of the observation sources is missing, or if the incoming data is rejected by the calculation. Individual observations will be if the incoming data is missing or older than the maximum allowed age.

For the Kalman Filter if a specific observation type is selected in the left panel, just the observations of that type are displayed in the right panel with the same information and display options as in the case of a Rigid Body calculation (see Calculations right panel details in Monitoring the Rigid Body Calculation). If a specific observation is selected, the right panel does not display anything.

If a Kalman Filter calculation is selected in the left panel, the right panel displays an overview of the Kalman Filter operation, including time series plots, and direct access to the calculation's controls (see Figure 6-23). This enables the user to monitor the performance of the incoming observations and how they differ from the calculated state estimates.

FIGURE 6-23 KALMAN FILTER CALCULATION MONITOR

The monitoring display consists of three main parts: the status grid, the calculation control interface Reset Calculation, and the time series displays.

6.9.3.1 Kalman Filter Status Grid

The Kalman Filter algorithm operates with Geographic2D observations and with optional velocity observations. If no velocity observations are present, the calculation is able to estimate a velocity based on the history of the position observations.

The grid consists of 4 rows: **Latitude, Velocity North, Longitude** and **Velocity East**. For each of these data items, the estimated value output from the Kalman Filter with a standard deviation is provided, the latest real observation is shown with a standard deviation. The age of the latest incoming observation is shown, followed by the status.

The status in this case indicates (good) if the observation has been accepted by the filter, and (bad) if the observation has been rejected by the filter.

6.9.3.2 How to Read the Time Series Data

When the Kalman Filter is just starting, the position and velocity sigma values will be very large. As data is received and the estimation begins to calculate, these errors will reduce greatly. If the filter is operating correctly, the error of position and velocity will increase with each calculation epoch, at a near constant rate, and then be brought back down by a subsequent update, so there will be a saw tooth pattern (Figure 6-24).

FIGURE 6-24 KALMAN FILTER VELOCITY SIGMA TIME SERIES

Likewise, the residuals increase with time in between observation updates, as the calculation is estimating new positions and velocities, while the latest updated value remains the same. Each incoming observation will reduce the position residual back to near zero, as long as that observation is accepted by the filter.

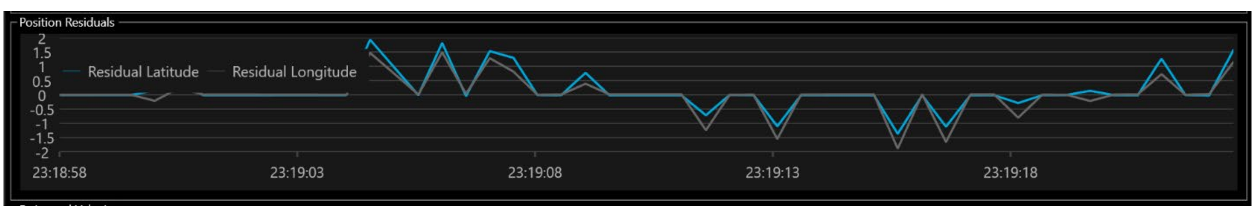


FIGURE 6-25 KALMAN FILTER POSITION RESIDUALS

In Figure 6-25 it can be seen that the position residual is centered around zero in both latitude and longitude, however the Latitude residual increases and then decreases, which is in time with the position or velocity updates.

Figure 6-26 shows the expected results of a correctly tuned Kalman Filter in the Map window. The yellow vehicle is using a Rigid Body Calculation with a geographic2D observation coming at 3 second intervals, similar to what would be the case for a USBL position update. The Kalman Filter calculation has the green snail trail. Note that although the raw Geographic 2D appears to the left and right of the track, it follows the same trend as the Kalman Filter calculation.

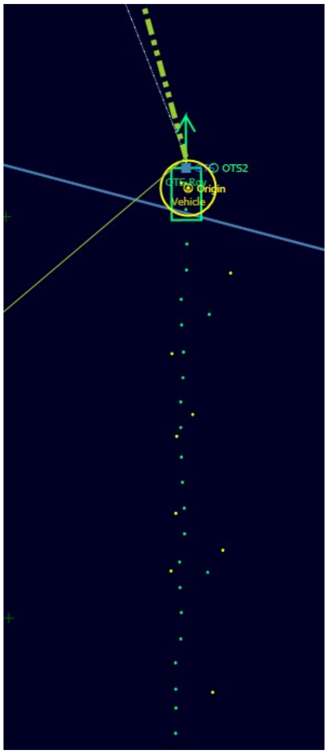


FIGURE 6-26 KALMAN FILTER MAP VIEW

The difference between a new observation and the estimated observation is known as the innovation. NavView uses a normalized innovation filter to automatically reject erroneous data. The innovation is scaled using the Kalman gain, which results in a unitless scalar value which will remain close to 1 for good data. Anything above 2.7 is rejected by the filter. In practice, this means that any observation further than approximately 2.7 * sigma (99%) away from the predicted position is rejected.

6.10 Static Draft Calculation

The Static Draft calculation accepts draft and attitude sensor input to determine a draft value for a CRP. The following observation types are supported as inputs:

- Geographic 2D (Elevation)
- Pitch/Roll (Attitude)

The calculation publishes the following observations:

- Elevation

This calculation operates on a timer executing every 5 seconds. Each sensor's draft is reduced to the CRP by applying the attitude data and an average of these is calculated and published as an Elevation observation.

6.10.1 Configure the Static Draft Calculation

The configuring of a Static Draft calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Static Draft calculation to be configured (see Edit a Calculation)

FIGURE 6-27 STATIC DRAFT CALCULATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Elevation Observations:** Add the Elevation observations providing the draft data (see Configuring Calculation Input Observations)

Note: The draft observation sources added are used in the calculation if their Use box is checked. Automatic failover does not apply to these observation sources. If one fails, it simply stops being used in the draft calculation.

4. **Pitch/Roll Observations:** Add the Pitch/Roll observations providing the attitude data required to reduce the draft sensor data to the CRP (see Configuring Calculation Input Observations)

Note: Automatic failover applies to the Pitch/Roll observations (see Automatic Failover)

5. Click Apply (if present, dependent upon the view used)

6.10.2 Monitoring the Static Draft Calculation

The resulting Static Draft can be monitored using the Time Series window.

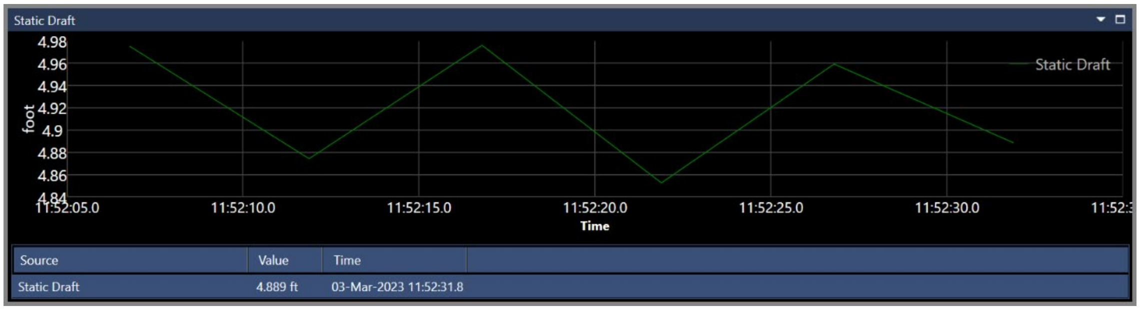


FIGURE 6-28 STATIC DRAFT – TIME SERIS

6.11 Seabed Elevation Calculation

The Seabed Elevation calculation provides a seabed elevation based on a body data source elevation, e.g. an ROV vehicle, and an Altitude sensor.

6.11.1 Configure the Seabed Elevation Calculation

The configuring of a Seabed Elevation calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Seabed Elevation calculation to be configured (see Edit a Calculation)

FIGURE 6-29 SEABED ELEVATION CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.
3. **Body Data Source:** Select the elevation source to be used from the drop-down list.
4. **Altitude Source:** Altitude can be entered as a constant value or taken from an observation.
5. **Correct for Attitude:** The option to correct for attitude is available if pitch/roll data is available.
6. **Sensor Lever Arm Offset:** Enter the offsets from the elevation sensor to the body reference point.

6.11.2 Monitoring Seabed Elevation Calculation

The Seabed Elevation calculation is monitored with the Calculation window. This is opened from the View ribbon by clicking on the Calculations button in the Windows section.

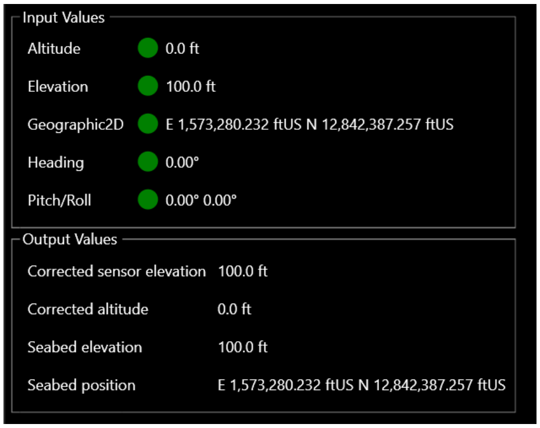


FIGURE 6-30 SEABED ELEVATION MONITOR

6.12 Relative Lever Arm Calculation

The Relative Lever Arm calculates the lever arm for selected position and elevation data sources based on a reference body, e.g. use a known DGPS derived vehicle position to check another DGPS antenna lever arm.

6.12.1 Configure the Relative Lever Arm Calculation

The configuring of the Relative Lever Arm calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Relative Lever Arm calculation to be configured (see Edit a Calculation)

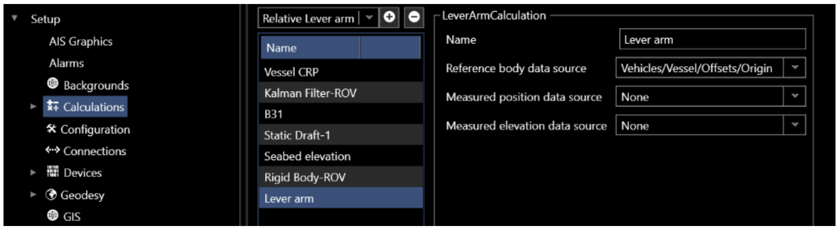


FIGURE 6-31 RELATIVE LEVER ARM CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Reference Body Data Source:** From the drop-down list select the reference body.

4. **Measured Position Data Source:** From the drop-down list select the position source to calculate the lever arm to.

5. **Measured Elevation Data Source:** From the drop-down list select the elevation source to calculate the lever arm to.

6.12.2 Relative Lever Arm Monitoring

The Relative Lever Arm calculation is monitored with the Calculation window. This is opened from the View ribbon by clicking on the Calculations button in the Windows section.

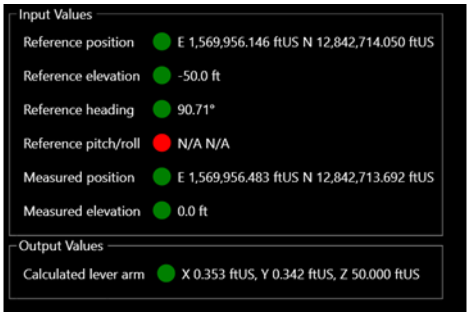


FIGURE 6-32 RELATIVE LEVER ARM MONITOR

6.13 Predicted Position

The Predicted Position calculation calculates a future position, heading and linear velocity (speed) of a body using the body's current position, linear velocity, heading, angular velocity (Rate of Turn) and look ahead time.

6.13.1 Configure the Predicted Position

The configuring of a Predicted Position calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Predicted Position calculation to be configured (see Edit a Calculation)

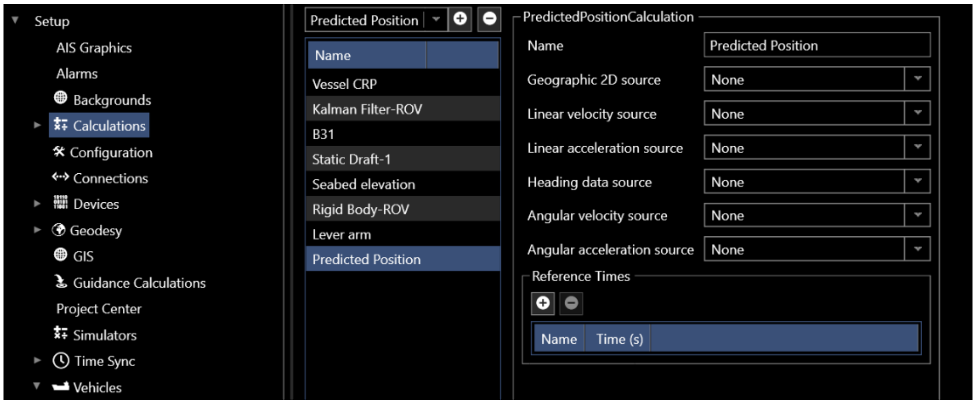


FIGURE 6-33 PREDICTED POSITION CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Geographic 2D source:** Select geographic 2D source of the body.

4. **Linear velocity source:** Select the linear velocity source of the body.

5. **Linear acceleration source:** Select the linear acceleration source of the body.

Note: The linear velocity and linear acceleration are required to be World Referenced.

6. **Heading data source:** Select the heading source of the body.

7. **Angular velocity source (Rate of Turn):** Select the angular velocity source of the body.

8. **Angular acceleration source:** Select the angular acceleration source of the body.

9. **Reference Times:** The time of the predicted position is from current time + look ahead in seconds (s). The prediction time is added using the button, this adds a configurable time as shown in.

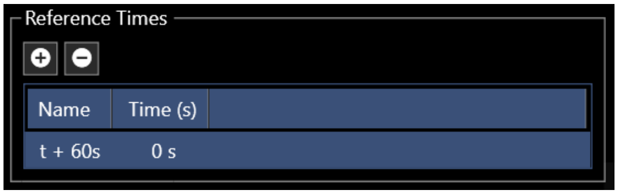


FIGURE 6-34 PREDICTED POSITION - REFERENCE TIMES

a. **Name:** Enter a name for the time reference
b. **Time (s):** Enter the time for the prediction in seconds

6.13.2 Monitoring Predicted Position Calculation

The calculated Predicted Position can be displayed as any observation type for monitoring purposes, e.g. in a Text Window, Time Series window, etc.

6.14 Depth From Pressure Calculation

The Depth From Pressure calculation calculates depth from a pressure observation using either the UNESCO or density algorithm. The calculation requires the following observation type:

- Pressure

Optionally, it can also accept the following observations instead of using a static manual data entry of the same:

- Pressure (Atmospheric)
- Geographic2D

This calculation publishes the following observations:

- Elevation
- Inputs

- Pressure (Atmospheric)
- Density
- Geographic2D
- Pressure (Raw)

This calculation operates on a timer updating at 2Hz if there is new data.

6.14.1 Configure the Depth From Pressure Calculation

The configuring of a Depth From Pressure calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Depth From Pressure calculation to be configured (see Edit a Calculation)

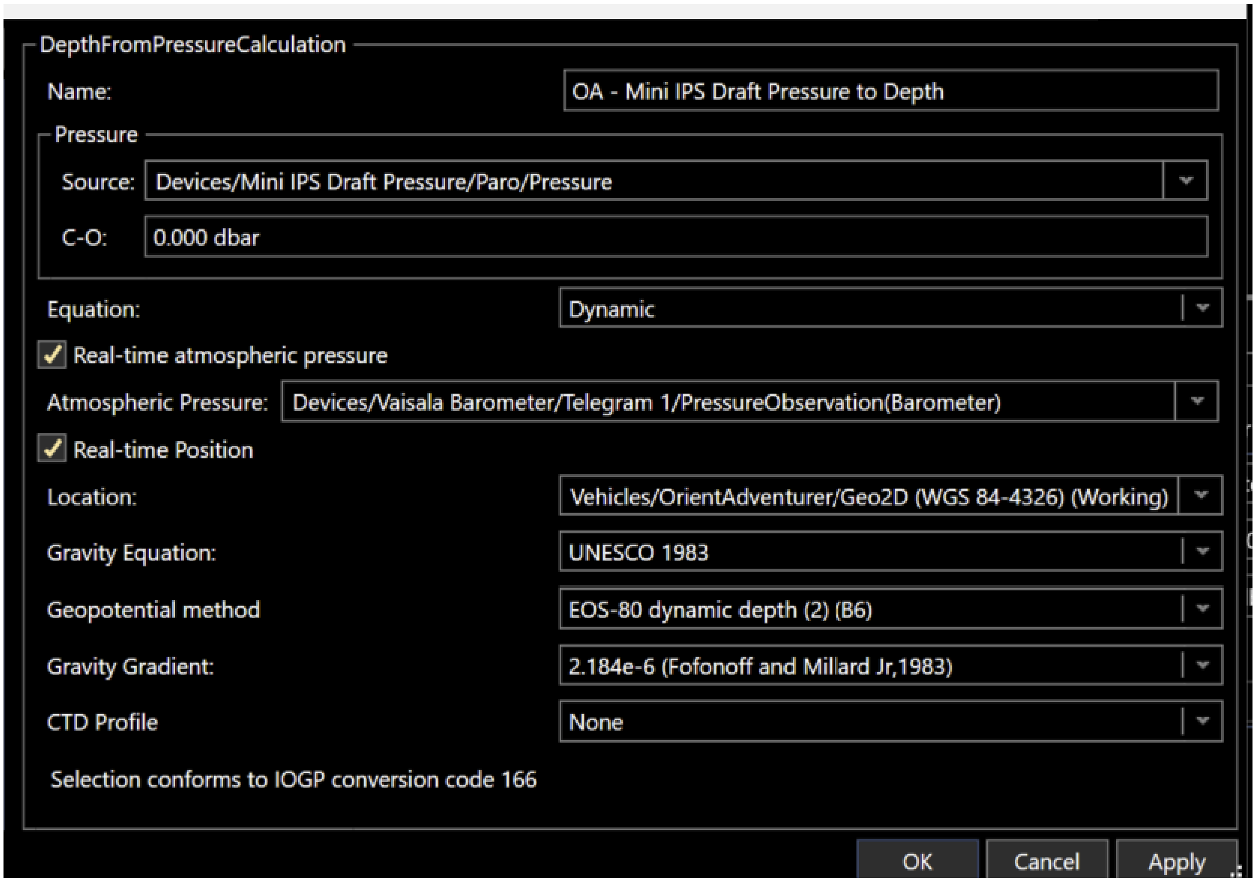


FIGURE 6-35 DEPTH FROM PRESSURE CONFIGURATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Pressure Source:** Select the pressure source to be used as a raw pressure source.

4. **Equation:** Select the calculation to be used to convert pressure to depth

a. **UNESCO**: The UNESCO equation refers to the 1980 Equations of State of Seawater, published in the UNESCO technical paper 44, referenced as UNESCO 1983. This equation uses a standard world ocean density and takes input of pressure and latitude
b. **Density**: The density equation requires a mean density of the water column, which can be determined from a Conductivity Temperature Density (CTD) profile of the water column. The Density value is entered into the Density text box and used for this calculation

The density equation is as follows:

$$Depth = \frac{P * 0.70307}{d} * \left(\frac{G_{std}}{G_{local}}\right)$$

0.70307 = psi to meters conversion for water of standard density

P = Pressure in PSI

d = mean density of the water column.

G_{std} = Standard gravity 9.80665 m/sec^2

G_{local} = local gravity from the International association of Geodesy, Special Bulletin on Geodesy (1970) ref: Anon 1970

$$G_{local} = G_e * (1 + 0.0053024 * sin^2\phi - 0.000059 * sin^2(2\phi))$$

G_e= 9.7803184 m/sec^2

c. **Dynamic:** Calculates depth using density from water column profile integrated to the input pressure. Provides most accurate result of three options

Note: The dynamic calculation implements dynamic depth equations described in IOGP Report 649 (Seawater Pressure to depth conversion). A combination of geopotential method and gravity settings must be chosen to adhere to this setup.

5. **Density:** The option to specify a fixed mean density value of the water column is available when the Density equation is selected.

6. **Geopotential Method:** This setting is available when the Dynamic depth method is chosen. Options available are:
   a. -EOS-80 dynamic depth (1) - Method Code B5
   b. -EOS-80 dynamic depth (2) - Method Code B6
   c. -EOS-80 dynamic depth (3) - Method Code B7

   The geopotential method forms the middle part in the IOGP conversion description. For instance, if method B6 is chosen, the conversion may be 165, 166 etc. If method B7 is chosen, the conversion may be 175, 176, 177.

   This option is only available when the dynamic depth method is selected.

7. **Real-time atmospheric pressure:** Check this box if the atmospheric pressure comes from a live pressure source.

8. **Atmospheric Pressure:** If the real time atmospheric pressure option is checked, select the real time pressure observation source from the drop-down list, otherwise enter the atmospheric pressure to be used in the calculation.

Note: The atmospheric pressure is subtracted from the pressure source prior to the depth being calculated.

9. **Real Time Position:** Check this box to enable the use of a real time position observation for the latitude used in the pressure to depth calculation.

10. **Location:** If the real time position is option is checked, select the real time position observation source that is to provide the latitude for the calculation, otherwise enter a position to be used in the calculation.

11. **Gravity Gradient:** Select the gravity gradient to use from the drop-down list.

12. **Gravity Equation:** Select the gravity equation to use from the drop-down list.

The following combinations of gravity equation and gradient constitute the IOGP report 649 Gravity methods:

Gravity Method Code	Gravity Equation	Gravity Gradient
C3	IAG1967	None
C4	UNESCO1983	None
C5	UNESCO1983	2.226e-6 (Saunders, 1981)
C6	UNESCO1983	2.184e-6 (Fofonoff & Millard, 1983)

The gravity method forms the last part (3rd digit) of the IOGP conversion code. If conversion 165 is specified for example, choose EOS-80 dynamic depth (2) B6, along with gravity equation UNESCO1983 and gradient 2.184e-6 (Fofonoff & Millard, 1983).

13. CTD Profile – If using the dynamic depth calculation method, a CTD profile must be specified which extends beyond the expected working pressure. The CTD profile must have at minimum fields for Pressure and for Density. IOGP report 649 details further requirements on the quality of the CTD profile to meet their standards.

14. Click Apply (if present, dependent upon the view used)

6.14.2 Monitoring Depth From Pressure Calculation

The calculated Elevation can be displayed as any observation type for monitoring purposes, e.g. in a Text Window, Time Series window, etc.

6.15 Generic Calculation

The Generic calculation creates observations by applying basic mathematical equations to multiple data source observations, e.g. add a Tilt Direction derived from pitch and roll to a Reference Heading to determine the Tilt Azimuth.

6.15.1 Configure the Generic Calculation

The configuring of a Generic calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Generic calculation to be configured (see Edit a Calculation)

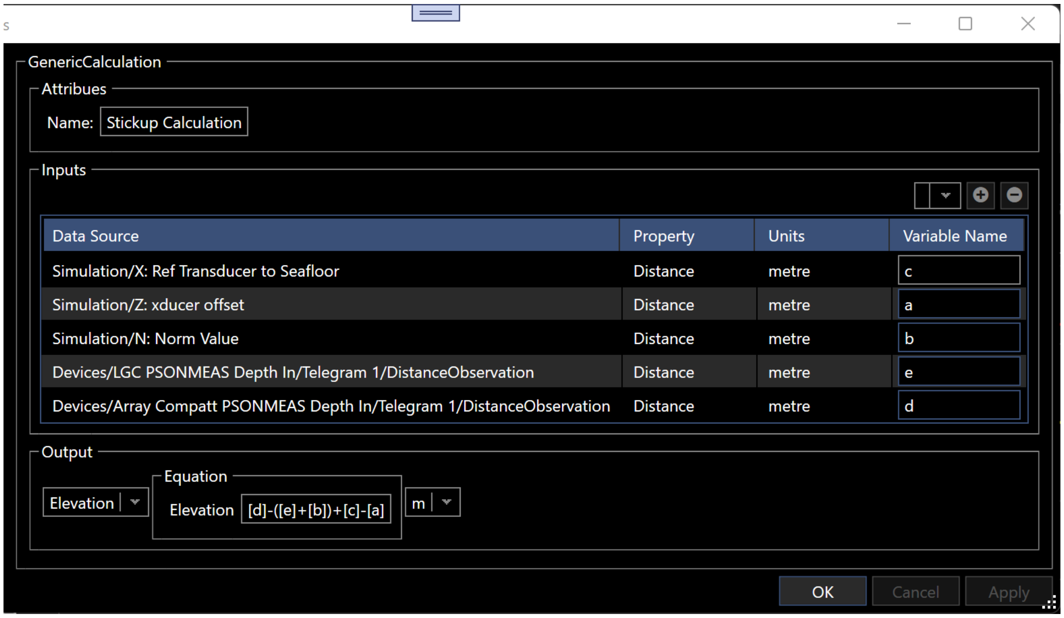


FIGURE 6-36 GENERIC CALCULATION CONFIGURATION DIALOG

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Inputs:** From the drop-down list select the data sources for the calculation and click the button to add it to the list of variables that will be available for the calculation.
   a. NavView will automatically increment the variable names alphabetically, e.g. A,B,C etc. These variables can be edited and a single letter or multiple letters like HDG used

4. **Output:** From the drop-down select the observation type the calculation result is to be published as, this allows the user to utilize the calculated result as a different observation type used in the calculation. For example, if a Depth is used in the

calculation but the output is set to be a Distance, the result can be used as a Distance observation elsewhere, but not as a Depth.

5. **Equation:** Enter a calculation equation to apply to the data sources that can evaluate to a value to generate an observation output.
   a. Variables are contained in box brackets
   b. Operators that can be used include:
      i. Plus: +
      ii. Minus: -
      iii. Divide: /
      iv. Multiply: *
      v. Modulo: %
      vi. Sine: Math.Sin()
      vii. Cosine: Math.Cos()
      viii. Tangent: Math.Tan()
      ix. π: Math.PI
      x. Absolute: Math>Abs()
      xi. Round Down: Math.Floor()
      xii. Round Up: Math.Ceiling()
      xiii. Brackets: ()
6. **Units:** From the drop-down list, select the units to use for the result. This list will be populated based on the Output data.

6.16 Heading From Positions Calculation

The Heading From Positions calculation determines an average heading from 2 or more positions. The calculation accepts the following observation type:

- Geographic 2D

The calculation publishes the following observations:

- Heading

This calculation operates on a timer updating once a second. All +possible pairings of the Geographic 2D observations are made and using their positions and sensor offsets, True heading values are determined for them. The average of these is published as a Heading observation.

6.16.1 Configure the Heading From Position Calculation

The configuring of a Heading From Position calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Heading From Position calculation to be configured (see Edit a Calculation)

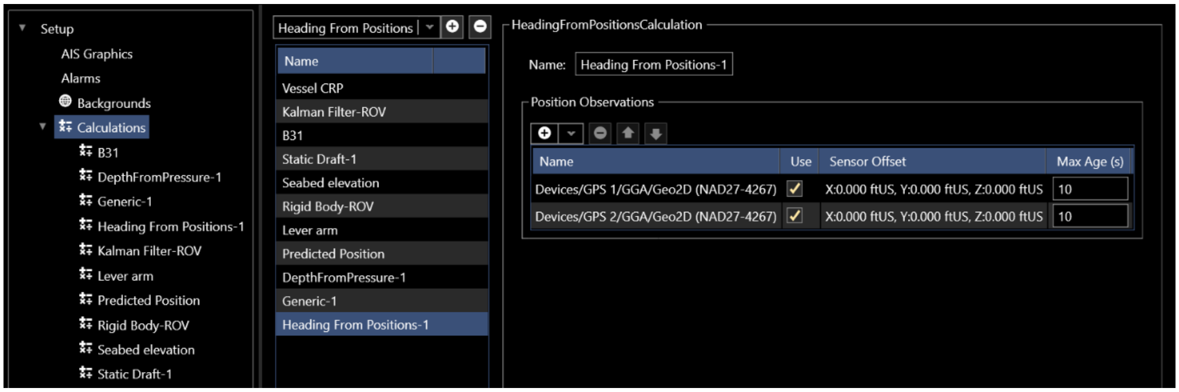


FIGURE 6-37 HEADING FROM POSITIONS CALCULATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Position Observations:** Add the Position observations to be used for the heading calculations and configure accordingly (see Configuring Calculation Input Observations)

Note: All of the Geographic 2D observations added are used in the calculation if their Use box is checked. Automatic failover does not apply to these observation sources. If one fails, it simply stops being used in the calculation.

4. Click Apply (if present, dependent upon the view used)

6.16.2 Monitoring the Heading from Position Calculation

Monitoring of this calculation is done using the Time Series QC Widget or displayed in a text window.

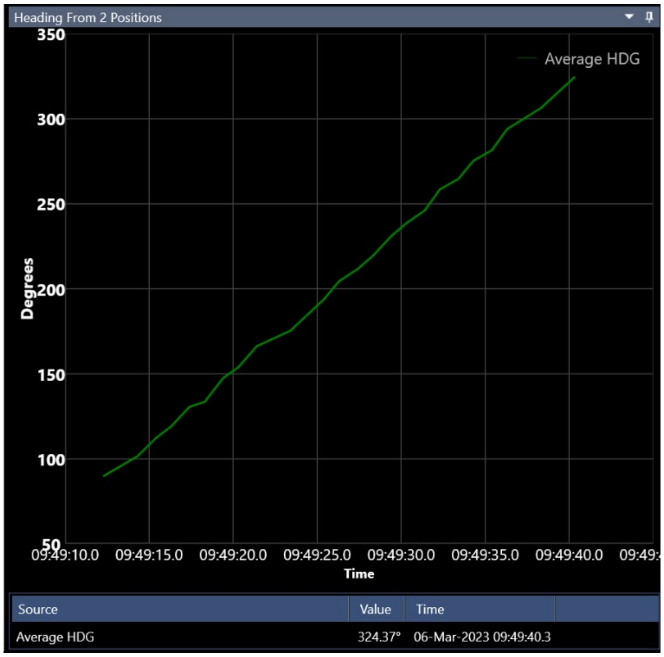


FIGURE 6-38 HEADING FROM POSITIONS TIME SERIES

6.17 Lookup

The Lookup calculation returns a value in a csv file corresponding to an input data source. The csv file contains a table of numbers in two columns. The data source looks at the values in the first column and then publishes the corresponding value in the second column. An example would be a calculated Layback based on a Station or KP of lay vessel.

6.17.1 Configure the Lookup Calculation

The configuring of a Lookup calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Lookup calculation to be configured (see Edit a Calculation)

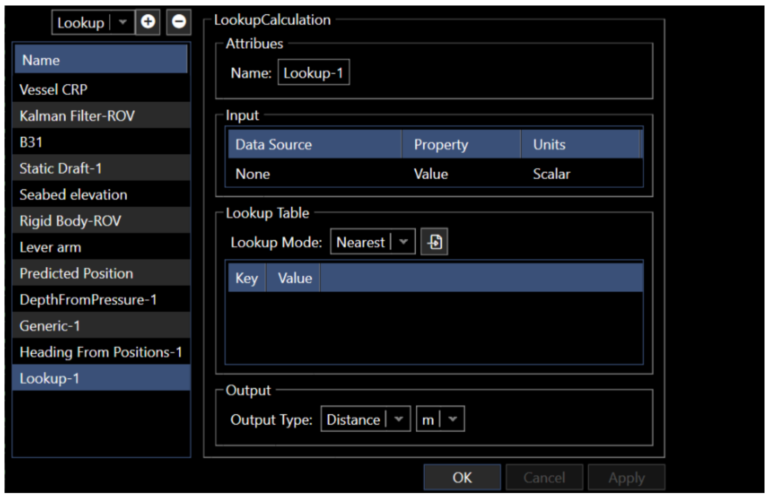


FIGURE 6-39 LOOKUP CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Input:** Select the data source which will correspond to the first column in the table. This can be defined as *Atleast, Interpolate or Nearest.*

4. **Lookup Table:** Select the csv file to be used in the lookup calculation by clicking . The values in the table will be displayed in the Lookup Table panel.

5. **Output:** Select the output type from the drop-down list.

6.18 DTM Elevation Calculation

The DTM Elevation calculation generates an elevation observation from a DTM based on a position observation data source and an Altitude source.

6.18.1 Configure the DTM Elevation Calculation

The configuring of a DTM Elevation calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the DTM Elevation calculation to be configured (see Edit a Calculation)

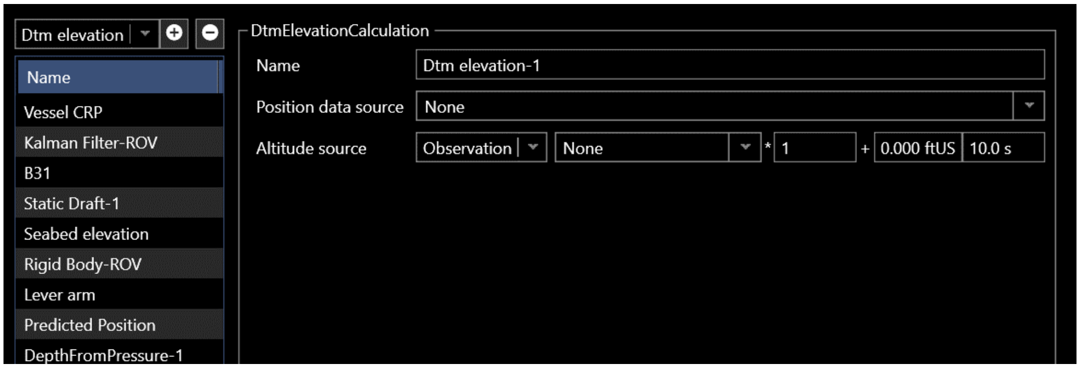


FIGURE 6-40 DTM ELEVATION CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Position Data Source:** From the drop-down list select the position source to determine the corresponding elevation from the DTM.

4. **Altitude Source**
   a. Select if Altitude source is an Observation (default) or a Constant
   b. If a Constant
      i. Enter a value
   c. If an Observation
      i. From the drop-down populated by all available Distance observation sources, select the one representing the altitude
      ii. Enter a multiplier to be applied to the observation value, e.g. enter -1.0 if the value's sign requires reversing
      iii. Enter a C-O to apply to the observation value after application of the multiplier
      iv. Enter the age of data to apply before the calculation will fail

6.19 Relative Position (Dynamic Body) Calculation

The Relative Position (Dynamic Body) calculations computes positions of remote targets using observations from total stations. The total stations would be setup on previously established body control points with known offsets to the body CRP. The remote targets would be mounted on previously established body control points with known offsets to the remote body CRP. The total station offsets are entered in the Lever Arm Offset section of the configuration page. The total station horizontal angle RO can be set directly in the total station using the local angle from the total station occupation point and RO point relative to the vessel centerline. Note that the angle is a local angle not a heading.

The calculation outputs:

- Remote target elevation
- Remote target Geographic2D
- Lever arm (body) X,Y,Z

The Lever Arm (body) X,Y,Z is referenced to the local Cartesian frame of the body the total Stations are setup on.

6.19.1 Configure the Relative Position (Dynamic Body) Calculation

The configuring of a Relative Position (Dynamic Body) calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Relative Position (Dynamic Body) calculation to be configured (see Edit a Calculation)

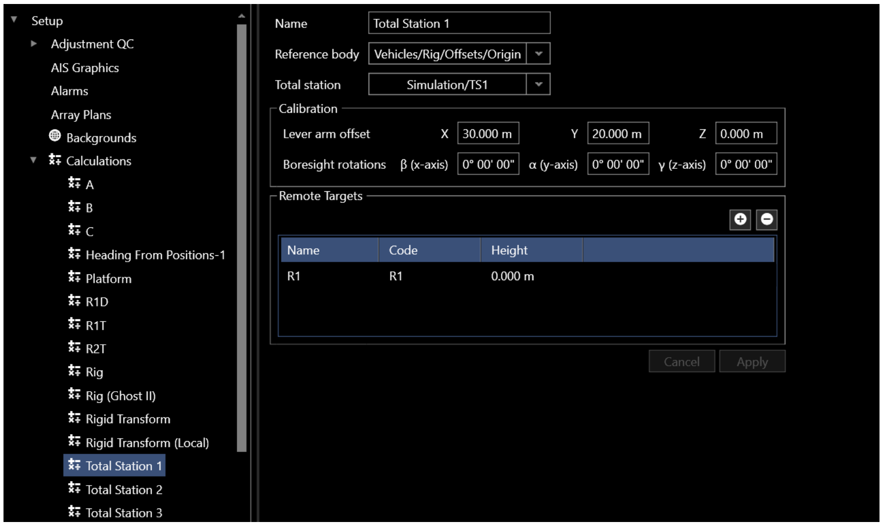


FIGURE 6-41 RELATIVE POSITION (DYNAMIC BODY) CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Reference Body:** Select the body from the drop-down list the total station is mounted on. This must be referenced to the body Origin/CRP.

4. **Total Station:** Select the total station from the drop-down list of devices.

5. **Calibration:** When the total station reference plane is not coincident with the vessel reference plane.
   - **Lever Arm Offset:** Total Station local offset from reference body CRP
   - **Boresight Rotations:** Any known total station axis misalignments can be entered here also the total station RO local angle can be entered here instead of entering the angle in the total station. The sign convention for the rotations about X, Y and Z follow the right handed CRS convention

6. **Remote Targets:** Target associated with the Total Station. The target is added using  button.
    - **Name:** Name given to target
    - **Code:** Code given to target
    - **Height:** Height of target from a vertical reference plane. This would be used to solve for a 3D solution

Note: Multiple instances of total stations can be configured.

6.20 Rigid Transform (Local) Calculation

The Rigid Transform (Local) calculation will determine the best-fitting rigid transformation that aligns two sets of corresponding points to solve for a position observation. For a 2D solution a minimum of two reference points in the set is required. This calculation takes as an input the remote target lever arm (body X,Y,Z) that was calculated from the Relative Position (Dynamic) calculation, the other input is the corresponding static offset on the body the target is mounted. The calculation transforms local coordinates (body Cartesian coordinates) into a second coordinate system (Geographic2D).

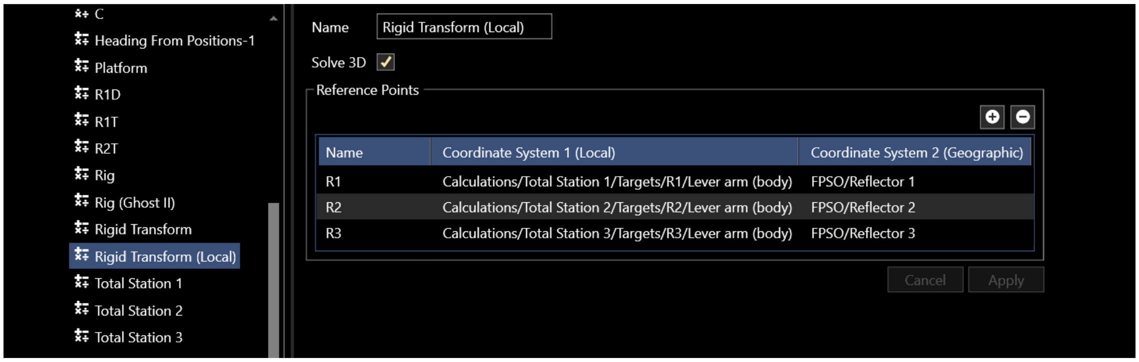
The calculation outputs:

- Remote target elevation, Geographic2D and Lever Arm transformation data
- Body origin elevation, Geographic2D and heading

6.20.1 Configure the Rigid Transform (Local) Calculation

The configuring of the Rigid Transform (Local) calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Rigid Transform (Local) calculation to be configured (see Edit a Calculation)



2. Figure 6-42 Rigid Transform (Local) Configuration

3. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

4. **Solve 3D:** Check this box if a 3D solution is required.

5. **Reference Points:** Select reference points for transformation.
   - **Name:** Name of remote target
   - **Coordinate System 1 (Local):** Target lever arm calculated from Relative Position (Dynamic) calculation
   - **Coordinate System 2 (Geographic):** Is the rigid body that the targets are on

6.21 Rigid Transform (Geographic) Calculation

The Rigid Transform (Geographic) calculation takes geographic coordinates from one body and transforms them to another. This calculation takes as an input the remote target geographic position as generated from the corresponding total station calculation; the other input is the rigid body containing the remote target offsets.

The calculation outputs:

- Body state origin elevation, Geographic2D and heading
- Remote target Geographic2D transformation data

6.21.1 Configure the Rigid Transform (Geographic) Calculation

The configuring of the Rigid Transform (Geographic) calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Rigid Transform (Geographic) calculation to be configured (see Edit a Calculation)

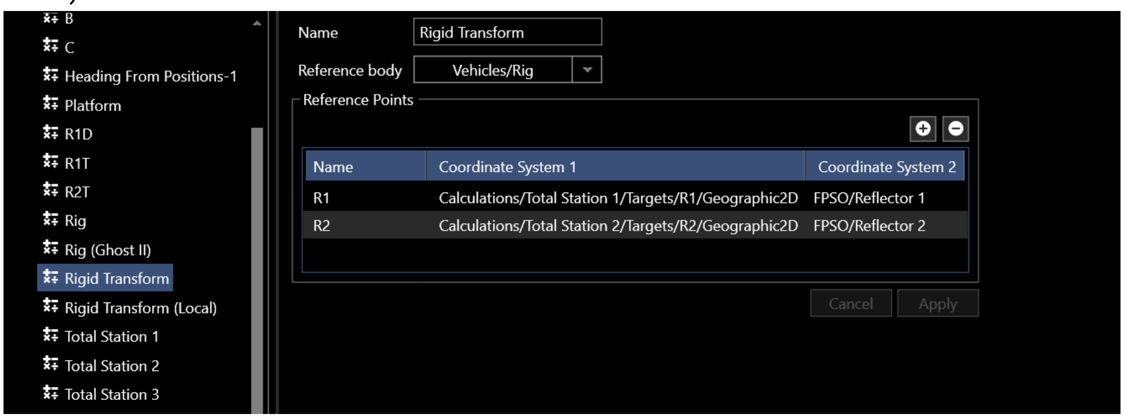


FIGURE 6-43 RIGID TRANSFORM (GEOGRAPHIC) CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Reference Body:** Select the body that has the reference positioning system.

4. **Reference Points:** Select reference points for transformation.
   - **Name:** Name of remote target
   - **Coordinate System 1:** Target Geographic2D data source from the corresponding total station calculation

- **Coordinate System 2:** Rigid body that the remote targets are on

6.22 Relative Position (Static) Calculation

The Relative Position (Static) calculation uses total station observations to compute positions of remote targets. The total station would be mounted on a static platform (e.g. shore based control). The occupation and backsight would be coordinated and these points are assigned as waypoints.

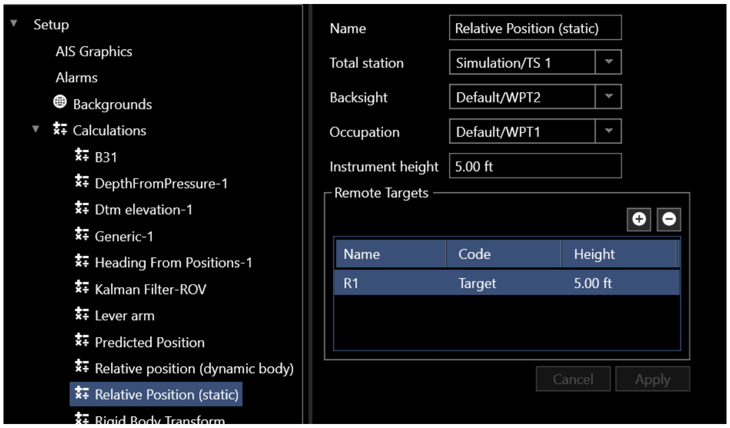


FIGURE 6-44 RELATIVE POSITION (STATIC) CONFIGURATION

The calculation outputs:

- Target elevation and Geographic2D

6.22.1 Configure the Relative Position (Static) Calculation

The configuring of the Relative Position (Static) calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Relative Position (Static) calculation to be configured (see Edit a Calculation)

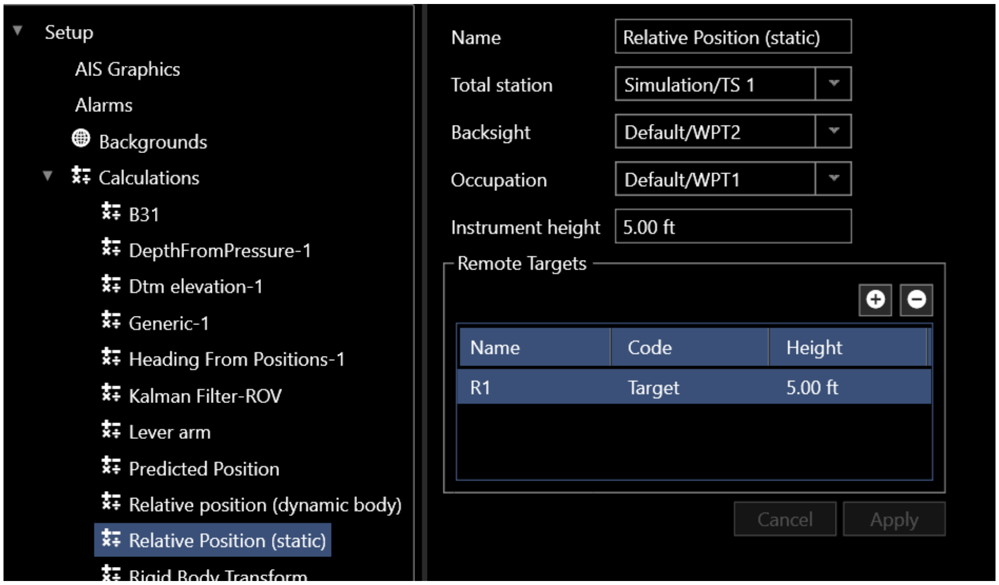


FIGURE 6-45 RELATIVE POSITION (STATIC) CONFIGURATION

2. **Name:** Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Total Station:** Select the total station to be used from the drop-down list.

4. **Backsight:** Select the backsight to use from the drop-down list, e.g. waypoint.

5. **Occupation:** Select the occupation to use from the drop-down list, e.g. waypoint.

6. **Instrument Height:** Enter instrument height for a 3D solution.

7. **Remote Targets:** Add a remote target using  button.
   - **Name:** Name of remote target
   - **Code:** Code of remote target
   - **Height:** Height of remote target from a vertical reference plane

6.23 Angular Acceleration Algorithm Calculation

In order to calculate Remote Motion (see Remote Motion Algorithm), the angular acceleration of a point on the rigid body is required. This is not readily available from motion sensors and therefore must be calculated.

Note: Angular velocity and angular acceleration are the same for all the points on the rigid body.

The Angular Acceleration Algorithm calculation accepts the following observation type:

- Angular Velocity

The calculation publishes the following observation:

- Angular Acceleration

6.23.1 Configure the Angular Acceleration Algorithm Calculation

The configuring of an Angular Acceleration Algorithm calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Angular Acceleration Algorithm calculation to be configured (see Edit a Calculation)

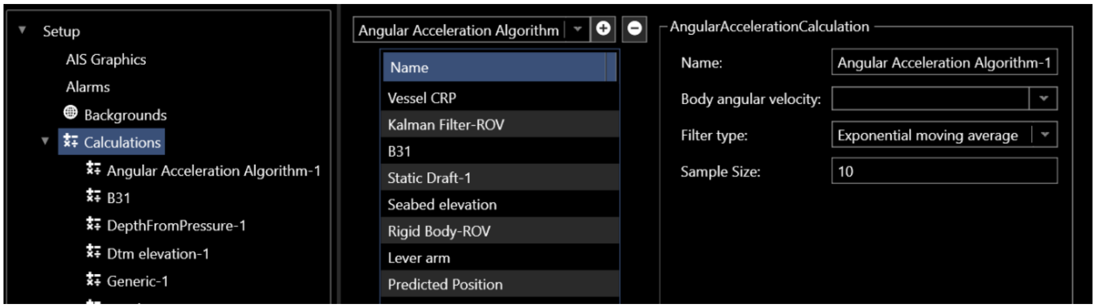


FIGURE 6-46 ANGULAR ACCELERATION ALGORITHM CALCULATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Body angular velocity**: From the drop-down list of all available sources of Angular Velocity observations, select the one to use in the calculation.

4. **Filter type**: From the drop-down list, select the filter to apply.
   a. **Exponential moving average:** Type of infinite impulse response filter that applies weighting factors to the observations that decrease exponentially over time never reaching zero, i.e. the weight applied to each observation in the sample decreases exponentially as they age. This is handled by multiplying the difference between the newest observation and the current average by α, where α =2.0 / (1.0 + sample size) and adding the result to the average
   b. **Modified moving average:** This is an exponential moving average where α =1.0 / sample size, i.e. the weighting decrease at a lesser rate than for the Exponential moving average
   c. **Simple moving average:** This is an unweighted moving average where with each new observation added to the sample, the oldest observation is dropped, and the average is simply the sample average
   d. **Fading memory:** This is a weighted average where the impact of the newest observation is determined by the filter gain. The difference between the newest observation and the current average is multiplied by 1 – Gain and added to the current average. The higher the Gain, the less impact the newest observation has on the average. A Gain of 0 results in no filtering

5. **Sample Size/Gain:** This is filter type dependent:
   a. If Exponential moving average or Modified moving average or Simple moving average, enter the sample size
   b. If Fading memory, enter the gain to use from 0.0 to 0.95 to apply where 0.0 is no filtering and 0.95 is high filtering

6. Click Apply (if present, dependent upon the view used)

6.23.2 Monitoring the Angular Acceleration Algorithm Calculation

The resulting angular acceleration can be monitored using the Time Series window.

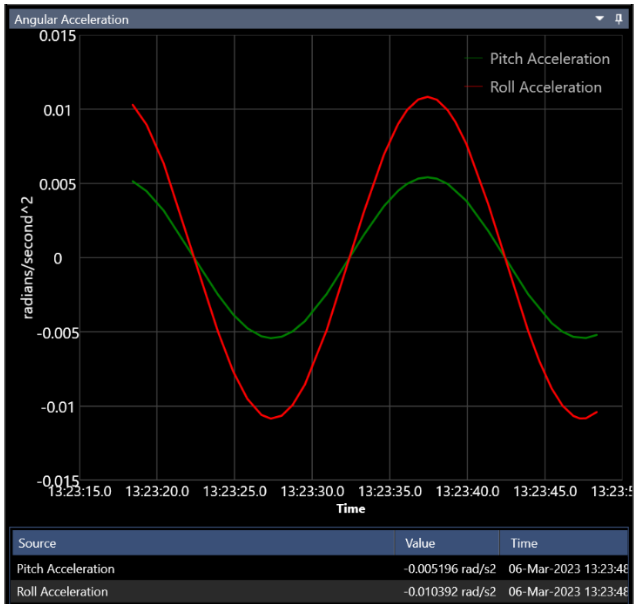


FIGURE 6-47 ANGULAR ACCELERATION TIME SERIES

6.24 Remote Motion Algorithm Calculation

- The Remote Motion Algorithm calculation provides the remote heave and/or motion for a given static or dynamic offset. The following input observation types are supported:
- Heading
- Pitch/Roll
- Heave
- Linear Velocity
- Linear Acceleration
- Angular Velocity
- Angular Acceleration

This calculation publishes the following observations, depending upon the configuration:

- With Heave and Pitch/Roll sensors assigned:
  - Remote Heave
- With Body Linear/Angular Velocity/Acceleration sensors assigned:
  - Linear Velocity (Body referenced)
  - Linear Acceleration (Body referenced)
- With Heading, Pitch/Roll and Body Linear/Angular Velocity/Acceleration sensors assigned:
  - Linear Velocity (World referenced)

- Linear Acceleration (World referenced)

The calculation publishes observations based on updates of the input sensors.

When a heave observation is received, the validity of the pitch/roll data is checked and if accepted, a remote heave is calculated for all defined targets and published as a Heave observation.

When any one of the linear or angular velocity or acceleration observations is received, the body referenced, and world referenced Linear Velocity and Linear Acceleration observations are published.

Note: When using the Remote Motion calculation, the NavView CRP should be selected to coincide with the vehicle's COG.

6.24.1 Motion Sensor Configuration and Output

It is important that the operation of the motion sensor used for this calculation and its output are understood.

Are the values output relative to the sensor's location or some other point as defined by a lever arm?

Most sensors support an option to enter a lever arm to relate its location to the vehicle's center of gravity (COG). This improves the modelling of the motion by the sensor. It is recommended this be applied in the sensor's configuration.

6.24.2 Configure the Remote Motion Algorithm Calculation

The configuring of a Remote Motion Algorithm calculation can be done when the calculation is first added or after. Therefore, the following steps start with the accessing of the calculation to be configured.

1. Access the Remote Motion Algorithm calculation to be configured (see Edit a Calculation)

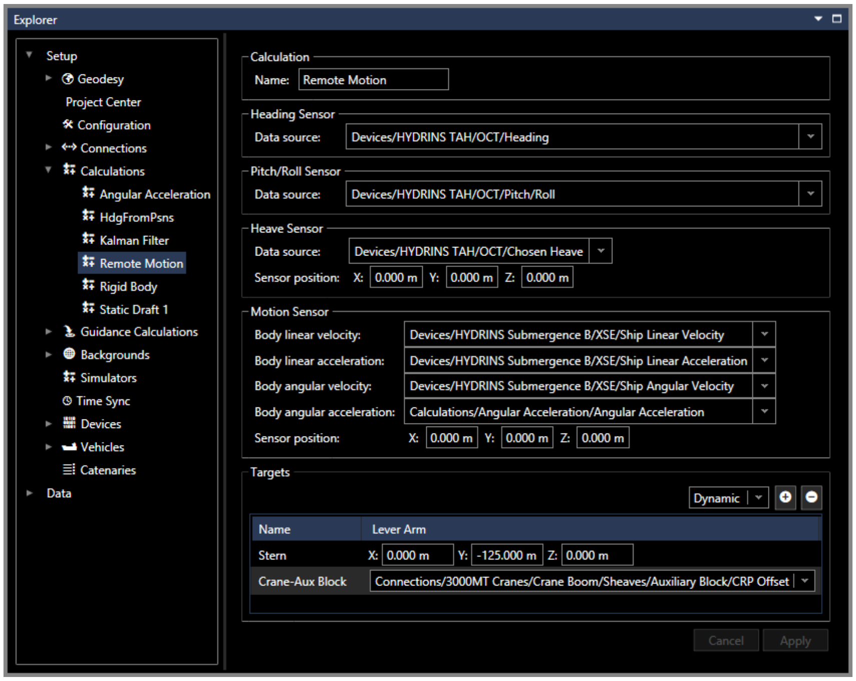


FIGURE 6-48 REMOTE MOTION ALGORITHM CALCULATION

2. **Name**: Enter a name for the calculation, it is recommended to keep the name short but still indicative of the calculation sources and/or purpose.

3. **Heading Sensor**
   a. Required to calculate and publish World referenced Linear Velocity and Linear Acceleration observations
   b. From the drop-down list of available Heading observation providers, select the desired source

4. **Pitch/Roll Sensor**
   a. Required to calculate and publish Remote Heave observations
   b. Required to calculate and publish World referenced Linear Velocity and Linear Acceleration observations
   c. From the drop-down list of available Pitch/Roll observation providers, select the desired source

5. **Heave Sensor**
   a. Required to calculate and publish Remote Heave observations
   b. From the drop-down list of available Heave observation providers, select the desired source
   c. If the heave data input is not relative to the CRP, enter the offsets of the point that the heave data is relative to from the CRP

6. **Motion Sensor**
   a. Required to calculate and publish Body and World referenced Linear Velocity and Linear Acceleration observations
   b. From the drop-down lists of each of the respective available observation providers, select the desired source

c. If the motion sensor observations are not relative to the CRP, enter the offsets of the point that the motion sensor observations are relative to from the CRP

Note: The offsets are only required for the linear velocity and acceleration observations. A single set of offsets are presented because only linear velocity and acceleration data from the same sensor should be used in the calculation. The rotational velocity and acceleration observations do not require an offset.

7. **Targets**
   a. Add the static or dynamic targets that the remote heave and/or remote motion are to be calculated for
   b. **Static Target**
      i. From the drop-down list, select Static
      ii. Click the ⊕ button to add a Static target to the data grid
      iii. Edit the newly added target in the data grid by clicking in the respective cell.
         A. **Name:** Enter a name for target
         B. **Lever Arm - X:** Enter the X offset (- to port, + to starboard) from the CRP to the target point
         C. **Lever Arm - Y:** Enter the Y offset (- aft, + forward) from the CRP to the target point
         D. **Lever Arm - Z:** Enter the Z offset (- down, + up) from the CRP to the target point
         E. **RMS Sample Period:** Enter sample period for RMS calculation. i.e. 00:01:00 is 1 minute
   c. **Dynamic Target**
      i. From the drop-down list, select Dynamic
      ii. Click the ⊕ button to add a Dynamic target to the data grid
      iii. Edit the newly added target in the data grid by clicking in the respective cell
         A. **Name:** Enter a name for target
         B. **Lever Arm:** From the drop-down list of available dynamic offsets, e.g. Crane Connection, select the one to calculate remote Motion for
         C. **RMS Sample Period:** Enter sample period for RMS calculation. i.e. 00:01:00 is 1 minute
   d. To remove an existing target
      i. Select the target in the data grid
      ii. Click the ⊖ button

Note: You are not prompted to confirm the removal of a Target and a removal cannot be reversed by clicking the cancel button.

8. Click Apply (if present, dependent upon the view used)

6.24.3 Monitoring the Remote Motion Algorithm Calculation

The results of the Remote Motion Algorithm can be monitored using the Time Series window.

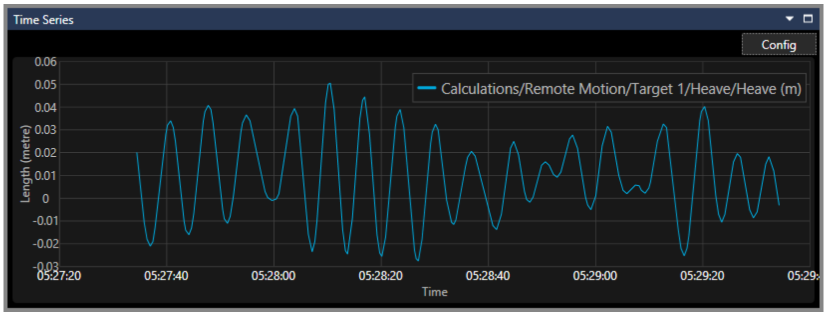


FIGURE 6-49 REMOTE HEAVE TIME SERIES

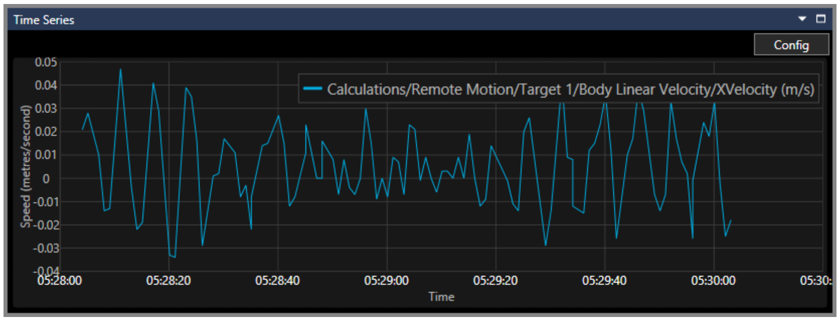


FIGURE 6-50 REMOTE LINEAR VELOCITY TIME SERIES

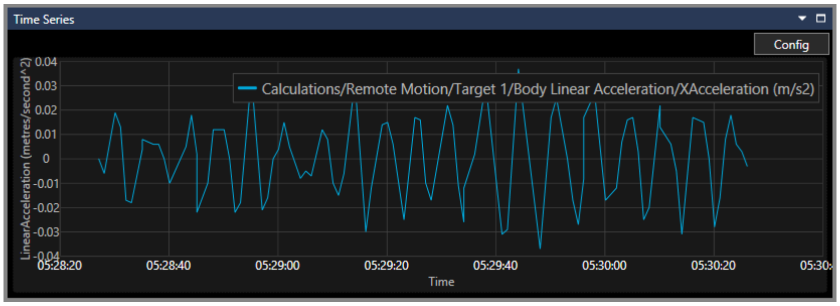


FIGURE 6-51 REMOTE LINEAR ACCELERATION TIME SERIES