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GMS Station SOH Monitoring User's Guide

Version 1.5 (for GMS PI 16 Open Source Release)

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ABSTRACT

This document is a user's manual for the Geophysical Monitoring System (GMS) Station State of Health (SOH) Monitoring User Interface.

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1. GENERAL OVERVIEW

The Geophysical Monitoring System (GMS) State-of-Health User Interface (SOH UI) is a web-based application that allows a user to view and acknowledge the SOH status of stations in the GMS system.

The SOH UI will primarily be used by the System Controller, who monitors and controls the system and external data connections. The System Controller uses the station SOH UIs to monitor, detect, and troubleshoot problems with station data availability and quality.
The SOH UI has 12 displays:

1) SOH Environment – an overview of station environmental issues by percentage per channel.

2) SOH Environment Trends – an overview of environmental issue changes over time per channel for each monitor type, i.e., the historical trend of an environmental issue.

3) SOH Lag – an overview of station lag per channel (in seconds).

4) SOH Lag Trends – an overview of changes in lag over time per channel, i.e., the lag's historical trend.

5) SOH Map – a map of station locations, where station color indicates worst-of or capability-based station SOH status.

6) SOH Missing – an overview of a station's percentage of missing data per channel.

7) SOH Missing Trends – an overview of percentage changes for missing data over time per channel, i.e., the historical trend in percentage missing data.

8) SOH Overview – a high-level summary of all available station and station group's SOH statuses, includes the ability to acknowledge any reviewed station's status.

9) System Messages – a time-ordered list of when stations need attention, SOH status changes/issues, user acknowledgements/quieting of station SOH status, and user comments.

10) SOH Timeliness – an overview of station timeliness per channel (in seconds).

11) SOH Timeliness Trends – an overview of changes in timeliness over time per channel, i.e., the timeliness's historical trend.

12) Station Statistics – a detailed summary of the SOH statuses for monitor types (monitors) and aggregate values. The monitors are lag (in seconds), percentage of missing data, timeliness (in seconds), and percentage of all environmental issues. Includes the ability to acknowledge any reviewed station's status.

The summary displays (SOH Overview and Station Statistics) allow the user to quickly evaluate the SOH status of all stations and station groups. The eight drilldown displays (SOH Lag, SOH Missing, SOH Environment, SOH Timeliness, SOH Lag Trends, SOH Missing Trends, SOH Environment Trends, and SOH Timeliness Trends) help troubleshoot specific issues for a selected station. The System Messages display provides real-time notifications for SOH related actions occurring within the system and is utilized for provenance purposes to assess the health of a station and what actions were taken during an interval of time. The Map display provides a visual of station locations and their SOH status.

Available station groups and time-intervals used in the calculation of SOH status are specified in the configurable files. Refer to the Configuration documentation for more information on these files.

This document is an in-depth user's guide of the SOH UI, including browser requirements and an overview of each interactive display.

2. BROWSER REQUIREMENTS

The UI is currently supported by Chrome (ver. ≥ 78), Firefox (ver. ≥ 68), and the open-source framework Electron (ver. ≥ 5.0.1). Note that docking and undocking tabs are currently not supported in Electron. The UI will also run on Apple's Safari and Microsoft's Edge, but likely with degraded performance.

3. LOGIN

To log into the SOH UI, enter the appropriate URL into a supported web browser. This URL will vary depending on where GMS is installed. After entering the URL, the user will be directed to the login screen (Figure 1).
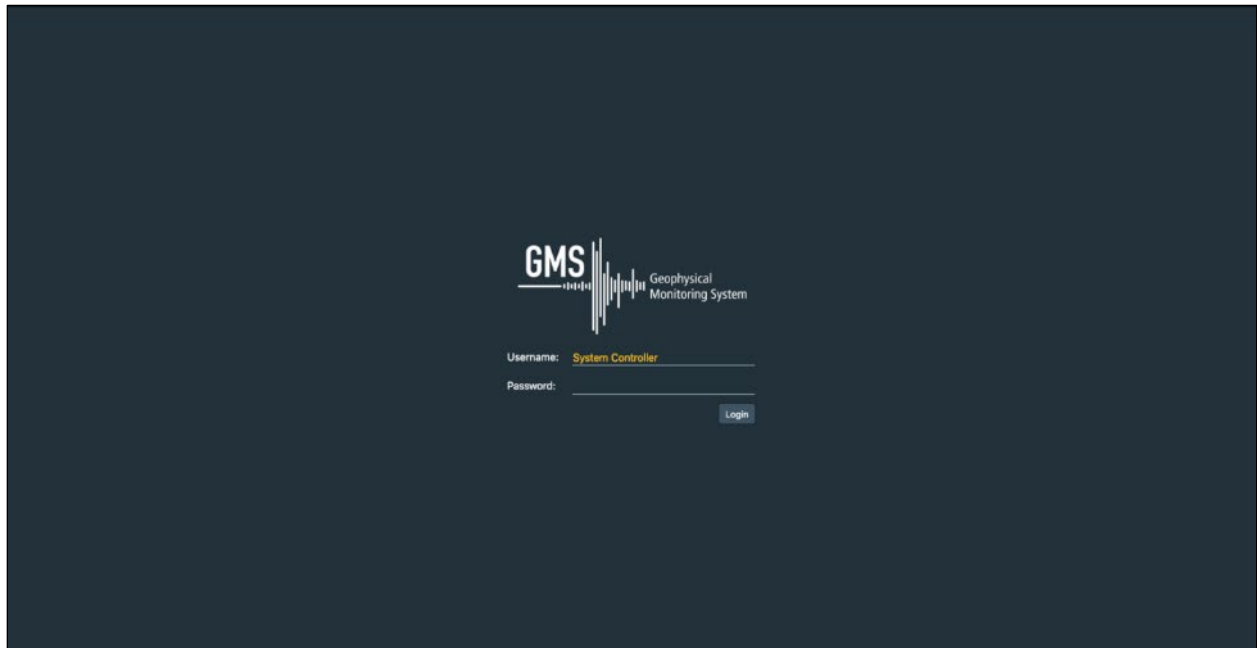
Figure 1. Login Screen for the SOH UI.

At the login page, user's should enter any username but leave the password blank; the user will not be able to enter information into the password field. User's should not enter credential information because this information is viewable within log messages.

4. DEFAULT WORKSPACE LAYOUT

After logging in, the user will be taken to the default SOH UI workspace layout (Figure 2).
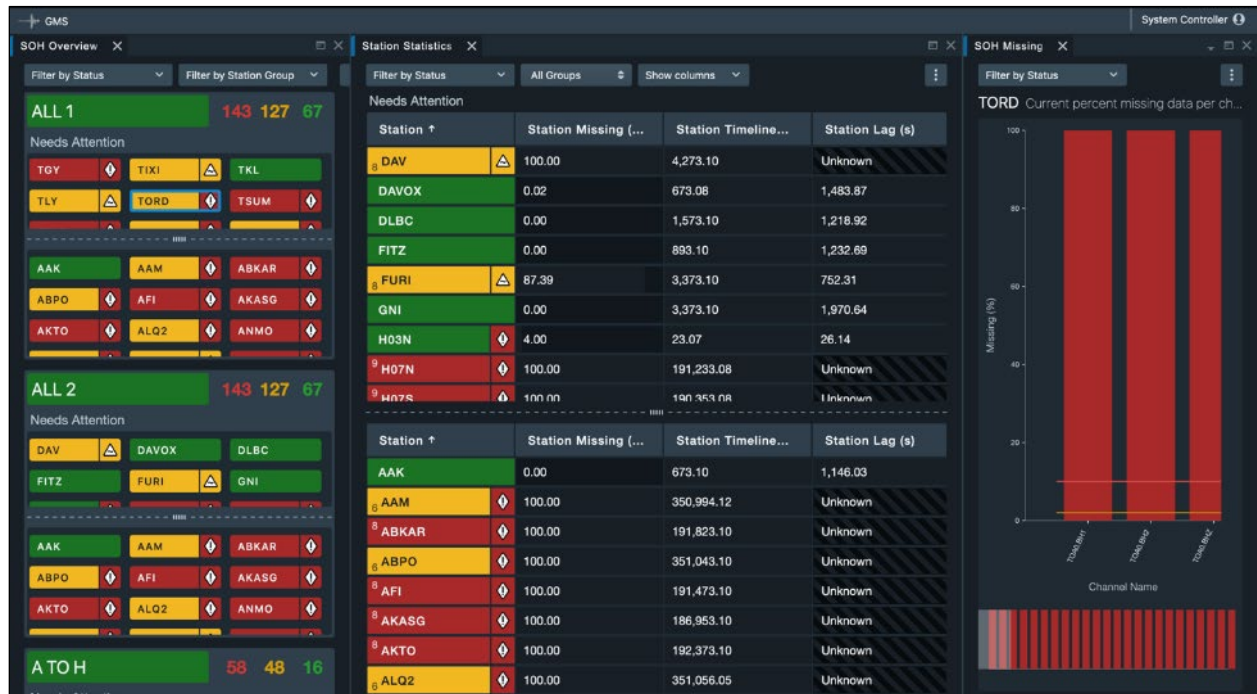
Figure 2. Default Workspace Layout of the SOH UI.

The default SOH UI workspace layout consists of six synchronized displays:

- SOH Overview (Figure 2, left)

- Station Statistics (Figure 2, center)

- SOH Missing, SOH Timeliness, SOH Lag, and SOH Environment (Figure 2, right)
    - These displays can be viewed by selecting the corresponding tab.
    - If the width of the default workspace is too narrow to show all drilldown display tabs, an arrow will appear to the right of the remaining tabs. Click the arrow to see a drop-down menu of the remaining displays. When a display is selected, it will replace the current drilldown display being viewed (e.g., SOH Missing in Figure 2).

The default SOH UI also includes an application level menu button labelled with the user's username in the top-right corner (Figure 3).
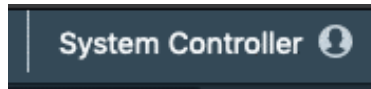
Figure 3. Application Level Menu Button.

The SOH Overview and Station Statistics displays are summary displays that provide high-level station SOH status information. The SOH Lag, Timeliness, Missing, and Environment displays are drilldown displays used to troubleshoot a selected station's channels for specific lag, timeliness, missing data, or environmental issues. Four additional drilldown displays (SOH Lag Trends, SOH Missing Trends, SOH Environment Trends, and SOH Timeliness Trends) are not shown in the default display and must be added by the user. The System Messages and Map displays are also not default. A station must be selected in either of the summary displays to populate the drilldown displays (see Section 5.4).

The default layout and any other user-defined layout can be modified by the user in six ways:

1) An individual display can be moved by clicking the corresponding tab and dragging it to the desired position; this includes placing multiple displays in one window with the display tabs next to each other (e.g., Figure 2, right).

2) An individual display can be expanded to full-screen by clicking the maximize button (i.e., box symbol) in the top-right corner of the display. Once full-screen, it can be returned to its original size by clicking the minimize button (i.e., dash symbol) at the top-right corner.

3) The horizontal dividers within the SOH Overview and Station Statistics displays, shown as dashed lines, can be shifted up and down by clicking and dragging the dashed line to the desired position; when a divider is selected, it will be highlighted blue. This action will vertically widen or shorten the category beneath the divider.

4) Displays can be widened horizontally by hovering the cursor over their window edge; when the window edge is highlighted blue, click and drag the edge to the desired position.

5) An individual display can be removed from the default layout by clicking the x next to the display name or the x in the top-right corner of the window containing the display. If multiple displays share a window, clicking the x in the window's right corner will result in those displays being removed.

6) Individual displays can be restored or added to the default layout by selecting one of the following options from the application level menu:

    a) Select SOH from the Displays section of the application level menu, then select one of the following display names:

i) SOH Environment

ii) SOH Environment Trends

iii) SOH Lag

iv) SOH Lag Trends

v) SOH Map

vi) SOH Missing

vii) SOH Missing Trends

viii) SOH Overview

ix) SOH Timeliness

x) SOH Timeliness Trends

xi) Station Statistics

This action will be described in greater detail in Section 5.1.

b) Select System Messages from the Displays section of the application menu. This action will be described in greater detail in Section 5.1.

c) Select Open Workspace from the Workspace section of the application level menu, then select SOH Layout (default).

   i) This restores the workspace layout to the default layout (Figure 2) unless a personalized layout was made default by the user (see Section 5.1).

d) Select Developer Tools, then select Clear Layout

   i) This restores the default workspace layout (Figure 2). If another workspace layout was saved as the default (see Section 5.1), this will restore to the saved default layout.

5. DISPLAY INTERACTIONS

5.1. Application Level Menu

The application level menu is shown in Figure 4. In the software, hovering over the About, Workspace, or Developer Tools options will provide a tooltip with a brief description.
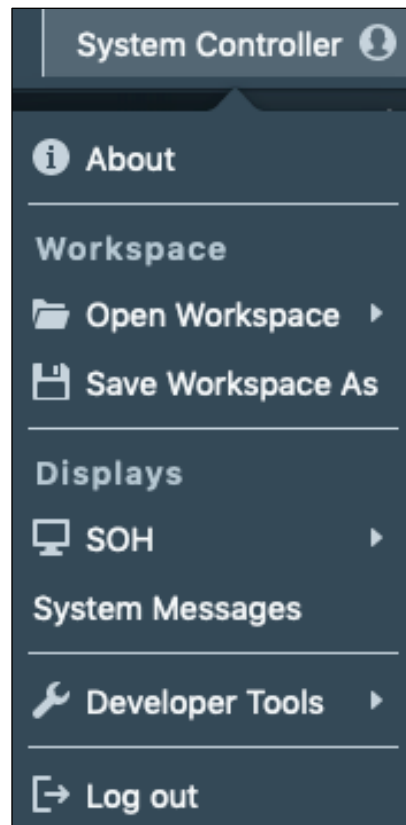
Figure 4. Application Level Menu Options.

Application Level menu options include:

1) About – Displays the version of the SOH UI and its latest commit. The latest commit is used by system developers for troubleshooting.

2) Open Workspace – Shows the user's available workspace layouts (Figure 5).
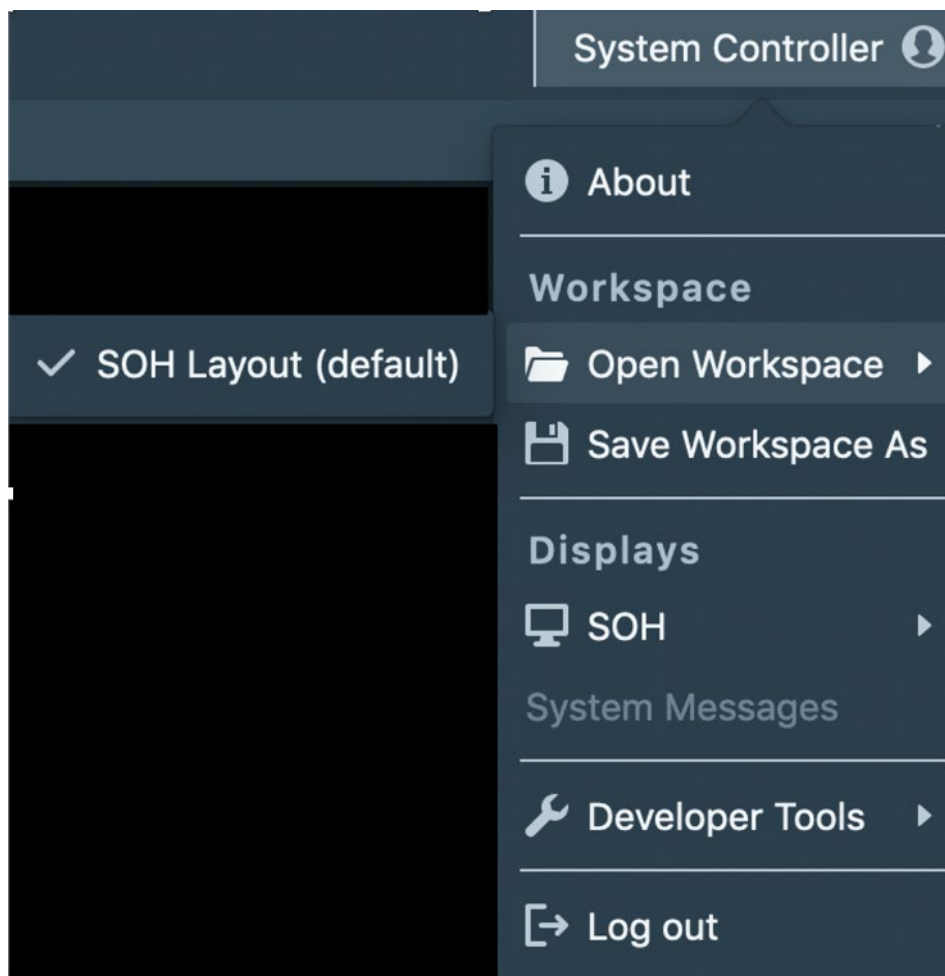
Figure 5. Open Workspace Menu Options.

Initially, only the default layout, SOH Layout, is available. More layout options are made available when the user saves them by selecting Save Workspace As. If the user makes changes to the current workspace layout and does not save it, they will be prompted to save or discard the changes when attempting to open another workspace (see Figure 6). A tooltip providing a brief description of each option can be brought up by hovering the cursor over the desired option.
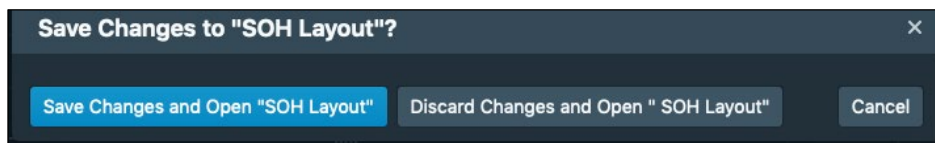
Figure 6. Prompt to Save or Discard Changes.

From the prompt, the user can choose to open a new workspace layout while either saving or discarding the changes. To save the changes, the user should select Save Changes and Open SOH Layout. To discard changes, the user should select Discard

Changes and Open SOH Layout. The user can also select Cancel to return back to the current workspace layout.

3) Save Workspace As –Saves a preferred UI layout (see Figure 7).
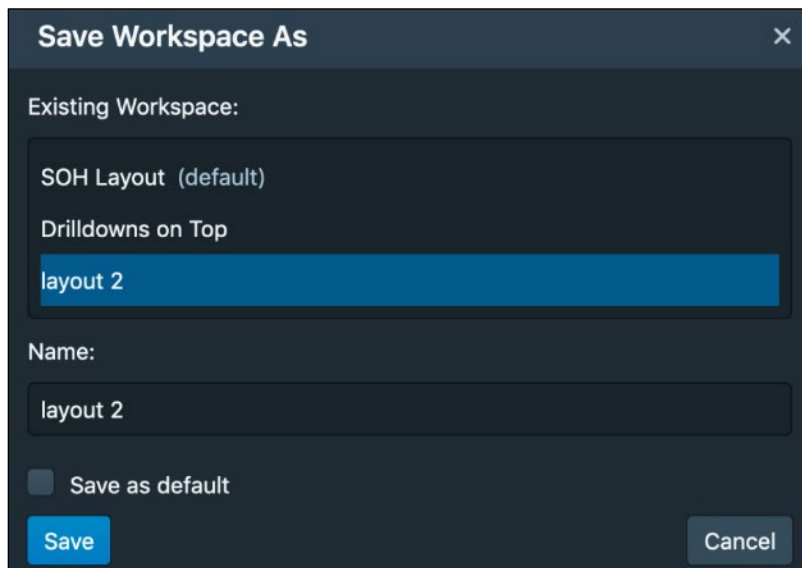
Figure 7. Save Workspace as Menu Options.

A new workspace layout can be saved under the name of an existing workspace layout by highlighting its name in the Existing Workspace dialog box or by typing the entry in the Name field. The user can make the new workspace layout the default by checking the Save as default option at the bottom of the context menu. Once saved, the new workspace layout can be accessed by going to Open Workspace (see bullet 2).

4) SOH – Adds workspace displays. Only one display instance can be open at a time. Displays already open are grayed out within the SOH submenu. For example, in Figure 8, the SOH Timeliness Trends display is grayed out because it is already open.
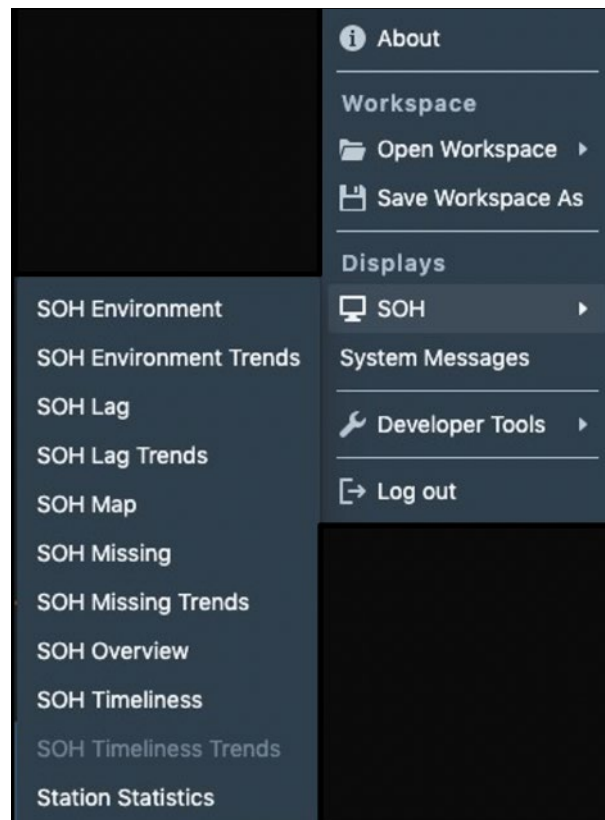
Figure 8. SOH Menu Options.

5) System Messages – Adds the System Message display (see Section 5.6).

6) Developer Tools – Provides the user two options:

    a) Logs – Lets the user view searchable logs tracked in the UI (debug, info, warn, error, fatal, etc.).

    b) Clear Layout – Resets the UI display to the default layout. This option resets the UI to the layout shown in Figure 2 if the user does not have a custom default layout.

7) Log Out – Logs the user out of the SOH UI. If any changes were made to the open workspace layout, the user will be prompted to save or discard the changes before logging out (see Figure 9). A tooltip providing a brief description of each option can be brought up by hovering the cursor over the desired option.
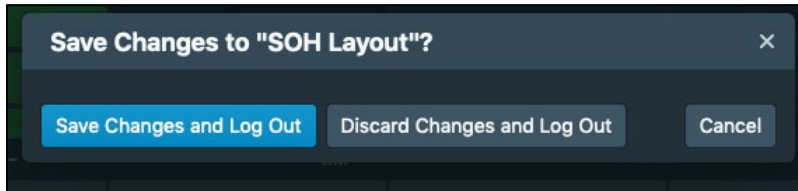
Figure 9. Log Out Menu Options.

5.2. SOH Overview Display

The SOH Overview display (Figure 10) provides a high-level overview of station SOH status. In this display, two types of SOH status are indicated:

1) Capability-based SOH status is used to prioritize which stations or station groups to troubleshoot first based on their importance to a configured capability.

2) Overall SOH status inherits from the station's worst channel/monitor (worst-of SOH status).

How these SOH statuses are determined is detailed in Section 7.

Figure 10. The SOH Overview Display.

In Figure 10, capability-based SOH status is indicated by the station tile color:

- green = good

- yellow = marginal

- red = bad

- dark gray/hash-marked = not configured to have a capability-based SOH-status

Worst-of SOH status is indicated by the color and shape of the badge at the right of each station tile. The badge will only be displayed if the overall station SOH status is marginal or bad.

1) yellow triangle = marginal

2) red diamond = bad

If no badge is shown, the worst-of SOH status is good.

The capability-based status or worst-of SOH status can be viewed on the screen by hovering the cursor over the desired tile or badge.

In the SOH Overview display, stations are sorted into one or more groups defined by a configuration file (see Configuration documentation). In each group, stations are sorted alphabetically. Groups can be any combination of stations and can share stations between them.

By default, all available station groups are shown in the SOH Overview display. The user can select which station group(s) to view by selecting the station group filter dropdown in the upper-left corner, see Figure 10, and checking all desired groups (Figure 11). Only station groups defined in the current configuration are shown in this dropdown.
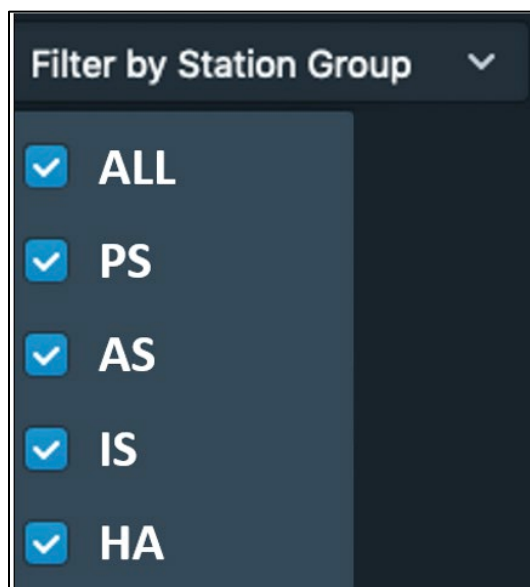
Figure 11. SOH Overview Filter by Group Dropdown.

A group's capability-based SOH status is indicated by the group's name color (e.g., Group PS has a good capability-based status in Figure 10). Also, a station shared between groups may have a

different capability-based SOH status depending on how its status was determined under a given capability configuration (see Section 7).

Worst-of SOH status works differently. Stations are always configured to have a worst-of SOH status, but a station group is not assigned a worst-of SOH status (see Section 7.1). The worst-of SOH status for a station shared between groups will not vary between groups.

In each group, the number of stations in a capability-based SOH status category is shown in the upper-right corner, where number color indicates the category (red = bad, yellow = marginal, and green = good). For example, in Figure 10, Group PS has 3 bad stations, 2 marginal stations, and 34 good stations. Stations that were not configured to have a capability-based SOH status (dark gray, hash-marked tile) will not contribute to this count. Thus, a group may have more stations than indicated. If a station group was configured to not have a capability-based SOH status, the three categories in the upper-right corner will show as gray zeros. Note that the number of stations in a worst-of SOH status category is never shown.

Both worst-of SOH status and capability-based SOH status are repeatedly updated at a configurable interval. The rough duration of this update interval is shown in the upper-right corner. To the left of the update interval, a Last Updated time-stamp indicates the most recent status update, i.e., the time the most recent channel is processed by GMS (Figure 12).

Figure 12. Time Stamp and Update Interval of Last Station/Capability-Based SOH Status Update.

Depending on the width of the Overview display, the user may need to click the colon symbol in the upper-right corner to view the update interval and/or the Last Updated time-stamp (see Figure 2). With each update, a station's reported worst-of SOH status or capability-based SOH status may change.

As shown in Figure 13, each station group is further subdivided into two sub-categories: Needs Attention (Figure 13, top) and an unlabeled category (Figure 13, bottom). These categories separate stations that have not been acknowledged by the user, (Figure 13, top), and stations that have been acknowledged (Figure 13, bottom). Acknowledgement will be addressed in the next section.

Figure 13. SOH Overview Display for Group PS.

5.2.1. Acknowledgment

When the SOH UI starts receiving data, all stations are placed in the unlabeled category at the bottom of the display (Figure 13) regardless of their initial SOH status (both capability-based and worst-of). Each station's SOH status is repeatedly determined (see Section 7) and updated at a predetermined interval (i.e., Update Interval).

If a station's SOH status changes during an update, the station will be placed in the Needs Attention category. Stations placed into Needs Attention will be assessed by the user. The user will acknowledge the station's status change by placing it back into the bottom category.

To place a station into the bottom category, the user can
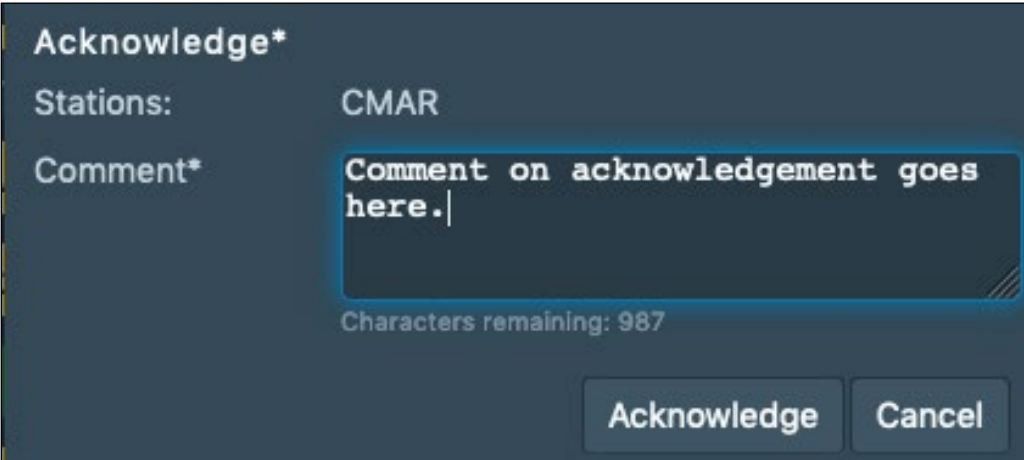
- Click the desired station and drag and drop it in the bottom category,
- Right-click the desired station and select Acknowledge station, or
- Right-click the desired station and select Acknowledge station with comment.

To place multiple stations at once into the bottom category, the user can

- Hold the Ctrl key (Command on Mac) while selecting the desired stations then perform the steps above or

- Click the initial desired station, press and hold Shift, and click again on the final desired station. This selects all stations between and including the initial and final clicked stations. Once the selections are made, perform one of the steps above.

Note that if acknowledgment of multiple stations via right-click is performed, the number of stations being acknowledged will be shown in the menu (e.g., Acknowledge 4 stations, Acknowledge 4 stations with comment). If a station in multiple groups is acknowledged, that station will be moved to the bottom category in all groups.

By selecting Acknowledge Station Status With Comment, the user can comment on the selected station(s), see Figure 14.

Figure 14. Text Area to Add Comment to Acknowledged Station.

The user's comment has a 1024 character limit. The characters remaining are listed beneath the text block. Once the comment is entered and the user selects the Acknowledge button, the selected station(s) are acknowledged and the related comment is stored in a database with the station(s) name, the comment timestamp, and the username (for provenance). The comment information is viewable in the System Message display (Section 5.6).

Once stations are in the unlabeled category, the user can view specific capability-based SOH statuses in the unlabeled category by clicking the Filter by Status dropdown in the top-left corner of the SOH Overview display (Figure 15). Note that None is a special status that occurs when a station is not configured to have a capability-based SOH status. Station tiles with a status of None will appear dark gray and hash-marked.
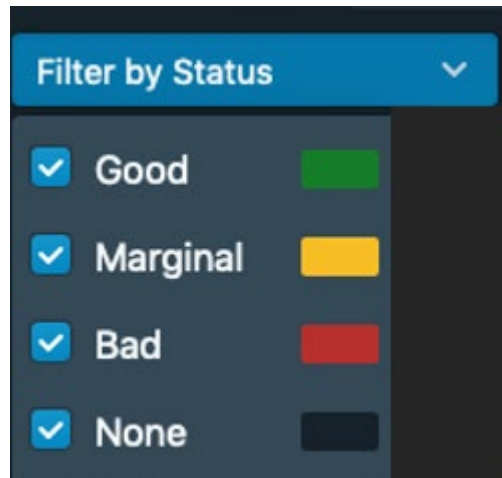
Figure 15. SOH Overview Filter by Status Dropdown Menu.

When a station's status is acknowledged in the SOH Overview display, all unacknowledged channel/monitor statuses for that station are acknowledged and quieted for a configurable period of time. During this quiet period, the user will not be notified of any additional status changes from the acknowledged channels/monitors. This quiet period can be cancelled or overwritten for one or more channels/monitors in the drilldown displays (see Section 5.4.9).

After the quiet period expires, there are several possibilities:

1) If no changes to the acknowledged channels/monitors occurred during the quiet period, the station remains in the bottom category.

2) If one or more changes occurred during the quiet period, the station is placed into Needs Attention after the quiet period expires.

3) If one or more unacknowledged channel/monitor statuses that were not manually quieted (see Section 5.4.9) change during the quiet period, the station is immediately placed in Needs Attention, even if the acknowledged channels/monitors are still in a quiet period.

An individual channel/monitor status can be quieted in the drilldown displays without being acknowledged. Quieting without acknowledgment has a different behavior than described here. See Sections 5.4.1, 5.4.5, and 5.4.9 for more details.

The SOH Overview display is synchronized with the Station Statistics display (see Section 5.3). Any changes to station status or acknowledgement in the Overview display will be reflected in the Station Statistics display and vice versa.

5.3. Station Statistics Display

The Station Statistics display (Figure 16) shows the capability-based SOH statuses of all available stations along with the worst-of SOH status of a station's worst available monitors (see Section 7).

Figure 16. The Station Statistics Display.

The default Station Statistics display shows nine columns/statuses:

1) **Station** – Station name and its capability-based SOH status as indicated by color (green = good, yellow = marginal, red = bad, and dark gray/hash-marked = not configured to have a capability-based SOH status). The station's worst-of SOH status is indicated by a badge to the right of the station name when the worst-of SOH status is marginal (yellow triangle) or bad (red diamond). If no badge is shown, the worst-of SOH status is good.

2) **Station Timeliness (s)** – The time difference (in seconds) between the current time and the most recent time a data sample has been acquired on any channel. Timeliness indicates how old the most recent data in GMS are. For instance, if GMS received its most recent data at 21:00 and it is now 22:00, the Station Timeliness would be 22-21 = 1 hr = 3600 seconds. Long timeliness values can result from dead stations/channels or because data are intentionally withheld for a period of time.

3) Station Lag (s) – Average transmission time (i.e., lag) across all channels over a configurable period of time. Lag is defined as the time difference (in seconds) between when data are recorded at a remote site and when they are acquired by the GMS system. Lag indicates how quickly data are transmitted from a station to GMS. For instance, if a station records data at 21:00:00 and the data are received by GMS at 21:00:30, the lag is 30 seconds.

4) Station Missing Data (%) – Shows the total percentage of missing data across all channels.

5) Station Issues (%) – Shows the total percentage of environmental issues across all channels and environmental monitors over a configurable period of time. Environmental monitors provide information related to station functionality in the field, e.g., whether backup power is unstable. A list of potential environmental monitors is provided at the end of this document.

6) Channel Timeliness (s) – Timeliness value and worst-of SOH status of the channel with the longest timeliness. A channel's timeliness is defined as the time difference (in seconds) between the current time and the most recent time a data sample was acquired on that channel. Channel timeliness indicates how old the most recent data are on that channel. See bullet 2 for an example of a timeliness calculation.

7) Channel Lag (s) – Lag value and worst-of SOH status of the channel with the longest lag, i.e., transmission time. Lag is defined as the time difference (in seconds) between when data are recorded at a remote site and when they are acquired by the GMS system. See bullet 3 for an example of a lag calculation.

8) Channel Missing Data (%) – Shows the percentage missing data value and worst-of SOH status of the channel with the highest percentage of missing data over a configurable period of time.

9) Channel Issues (%) - Shows the percentage issues data value and worst-of SOH status of the channel with the largest percentage of environmental issues on a single channel/environmental monitor pair over a configurable period of time.

For the Channel columns, the worst-of SOH status for each monitor type/station pair (e.g., Channel Timeliness for station CMAR in Figure 16) is indicated by color:

- gray = good,

- yellow = marginal,

- red = bad,

- dark gray = non-defining, i.e., the monitor type for that station does not contribute to the calculation of any SOH status listed in the Station column (see Section 7)

- dark gray/hash-marked = no data received for a non-defining monitor type, and

- yellow/hash-marked = no data received for a monitor type intended to be defining.

Note that the meaning of the dark gray/hash-marked tile in the Channel columns differs from the meaning defined in bullet 1 of this section for the Station column. For the Channel columns, which contain data to be used in the determination of Station SOH statuses, a dark gray/hash-marked tile indicates no data were received. For the Station column, which does not contain data but rather the SOH statuses of a station, a dark gray/hash-marked tile indicates that station was not configured to have a capability-based SOH status.

The remaining Station columns, Station Missing data (%), Station Timeliness (s), Station Lag (s), and Station Issues (%), represent aggregate values for the station and are considered statistics only. These columns' cells are gray; this color does not represent any SOH status since these columns do not contribute to any SOH status calculations. However, if there are no data available to calculate an aggregate, these cells will also be colored dark gray/hash-marked.

Specific columns can be selected for viewing by selecting the Show columns dropdown menu at the upper left of Figure 16. The dropdown menu is shown in Figure 17 below.
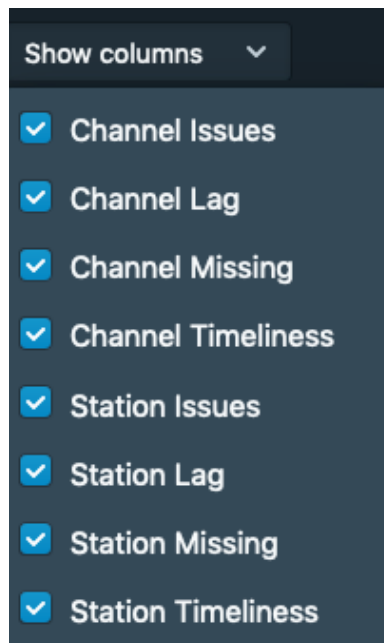
Figure 17. Station Statistics Column Dropdown Menu.

When an option is selected/deselected, the column corresponding to that option will/will not be shown.

For the Station/Channel Missing (%) and Issue (%) monitors, the percentage of missing data or environmental issues is indicated by cell fill as well as by a numerical percentage value (Figure 18). The percentage of cell fill should match the numerical percentage value written on top.
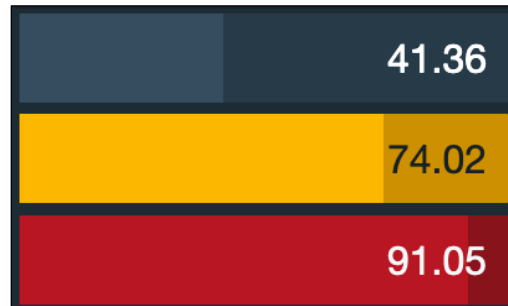
Figure 18. Percentage Cell Fill in Channel Missing and Issues (%) Columns.

By default, the above information is shown for all available stations from all available station groups. Stations in multiple groups are only shown once. Thus, the SOH status shown in the Station column represents a station's worst available capability-based SOH status amongst all groups. This status should correspond to at least one of the capability-based SOH statuses shown for the same station in the Overview display.

The numbers left of the station name in the Station column (Figure 16) indicate the number of groups in which a station has a bad (top number) or marginal (bottom number) capability-based SOH status. For example, in Figure 19, station ARCES has a bad capability-based status in 4 groups and a marginal capability-based status in 1 group.

If a station's worst available capability-based SOH status is also the only instance of a bad or marginal status amongst all groups, the corresponding bad or marginal count will be blank. An example would be station BRMAR (Figure 19), whose worst available capability-based SOH status of bad (red tile) is also the only instance of a bad status for BRMAR amongst all groups. Note in this example that because a bad SOH status is worse than marginal, a value of 1 is shown in the marginal count for BRMAR, even though it is also the only instance of a marginal status for BRMAR amongst all groups.

Figure 19. Counts of Bad and Marginal Capability-Based Statuses for Stations ARCES and BRMAR.

To view stations from a select group, the user selects All Groups from the dropdown (upper-left corner of Figure 16) and selects a group to view in the Station Statistics display. When a group is

selected, the dropdown button label will change from All Groups to the selected group name, e.g., PS. The tile color in the Station column now represents the capability-based SOH status of the station for that group. It should match the station status shown in the corresponding group in the Overview display. The counts on the station name's left will no longer be shown. The badges indicating worst-of SOH status will remain the same, since station worst-of SOH status does not vary by group.

Similar to the SOH Overview display, the Station Statistics display is split into two categories: Needs Attention (Figure 16, top) and an unlabeled category containing stations that have been acknowledged (Figure 16, bottom). The unlabeled category can be filtered by capability-based SOH status by selecting one or more statuses from the Filter by Status dropdown menu (upper-left corner of Figure 16, see Figure 15 for the menu).

These categories, and station acknowledgement in general, function similarly to the SOH Overview display. Please refer to Section 5.2.1 for more information.

5.3.1. Station Statistics Display Workspace Layout

The Station Statistics display shown in Figure 16 represents its default layout. In addition to the layout options described in Section 4, the top (Needs Attention) and unlabeled categories in Figure 16 can be further modified in five ways:

1) The columns' position can be rearranged by clicking anywhere in the column title cell and dragging the column to the desired position.

2) Column width can be modified by hovering over a column title edge until a double-arrow symbol appears. Then the user can click and drag the column edge to the desired width.

3) Columns can be added or removed by deselecting the column from the Show columns dropdown menu (see Figure 17). Note that the Station column cannot be removed.

4) Station names can be sorted alphabetically, ascending or descending, by clicking the arrow symbol (Figure 20) to the right of the Station column title. By default, station lists are sorted ascending (arrow points up). To change to descending, click once anywhere in the column title, except on the bar menu button (far right of Figure 20) which is used to open the filter menu (bullet 5).

Figure 20. Sorting Arrow for Station Column.

5) Stations can be sorted by increasing or decreasing Station/Channel Timeliness, Lag, Missing (%), or Issues (%) by hovering over the respective column title and clicking to bring up an arrow symbol (similar to Figure 20). The arrow will point up for increasing value, down for decreasing value. By default, these columns are not sorted. When sorting by one of these monitors (columns), the position of a station in the list may change with every update as the monitor value changes. The arrow symbol will only be visible in the column being sorted.

6) Rows can be filtered to show one or more desired stations by hovering to the far right of the Station column title to bring up a bar menu button (Figure 21).

Figure 21. A Close-up of the Bar Symbol Used to Pull Up a Filter Menu.

When this button is clicked, it will bring up a filter menu (Figure 22, center). When a value is entered into the filter field, the menu expands giving the option to apply another AND/OR filter (Figure 22, right) with its own filtering options (Figure 22, center). This option can be used once. Once the values are entered, click anywhere in the display to hide the filter. A funnel shaped symbol will appear to the right of the Station column title, indicating a filter is in place. To remove the applied filter, bring up the filter menu once more and delete the entered value(s).

Rows can also be filtered by any of the station or channel column values (e.g., Station Timeliness, Channel Missing). The actions are the same as described above for the Station column.
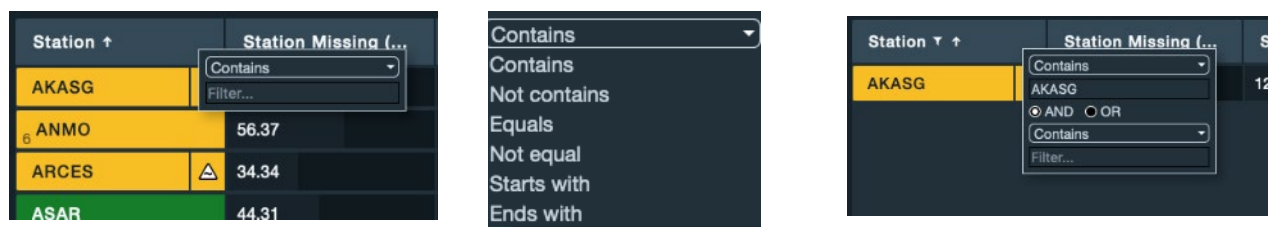
Figure 22. Station Filter Application. (Left) Available Filter Options (Center) Menu Expansion for Applying Another AND/OR Filter (Right).

5.4. SOH Drilldown Displays

The SOH drilldown displays troubleshoot specific monitors for a selected station. Currently, these monitors are Lag, Timeliness, Missing (%), and Issues (%), i.e., Environmental Issues, which were defined in Section 5.3.

To populate a station drilldown display, the user must first select a station in the SOH Overview or Station Statistics display. Because they are synced, a station selected in the Overview display will also be selected in the Station Statistics display and vice versa. The selected station can come from any group and can be in the Needs Attention category or the unlabeled category containing acknowledged stations. Once selected, the station will then be highlighted in blue in both displays as shown in Figure 23.
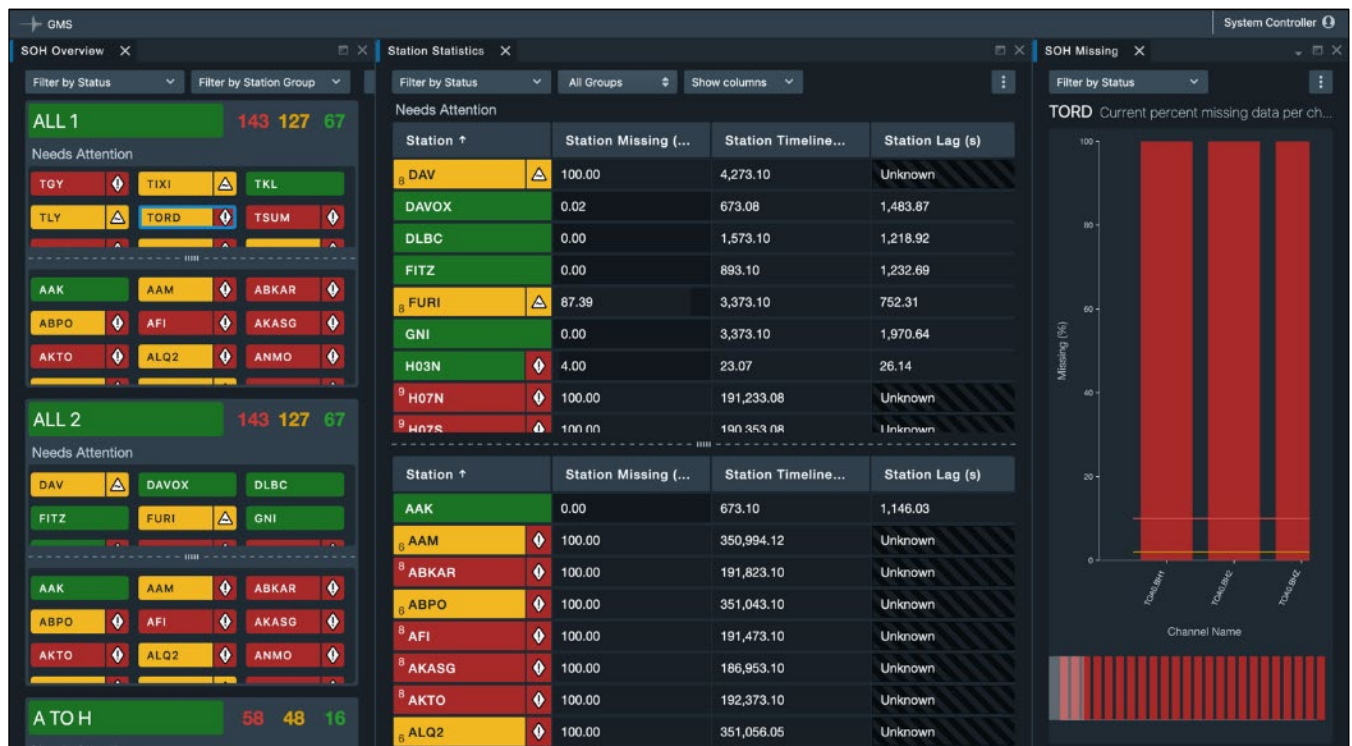
Figure 23. The SOH UI Default Layout with Station TORD Selected.

In Figure 23, station TORD has been selected. Each instance of TORD in the summary displays is highlighted by a blue box. The four SOH UI default layout drilldown displays (right) are populated with the corresponding information for TORD. To view a particular drilldown display, e.g., Missing, click on the desired tab. If the workspace is too narrow to show all four tabs, an arrow will appear to the right of the visible tabs. Click the arrow to see a drop-down menu of the remaining displays. When a display is selected, it will replace the current drilldown display being viewed (e.g., SOH Missing in Figure 23).

The SOH Lag Trends, Timeliness Trends, and Missing Trends drilldown displays (not shown) will also be populated with station information if they are added to the workspace layout (see Sections 4, 5.1, 5.4.2, 5.4.4). An additional step is required to populate the SOH Environment Trends drilldown display (not shown); this additional step is described in Section 5.4.6.

In the drilldown displays, only one station can be selected at a time. If multiple stations are selected in the SOH Overview or Station Statistics displays, the user will be instructed to select only one station (Figure 24).
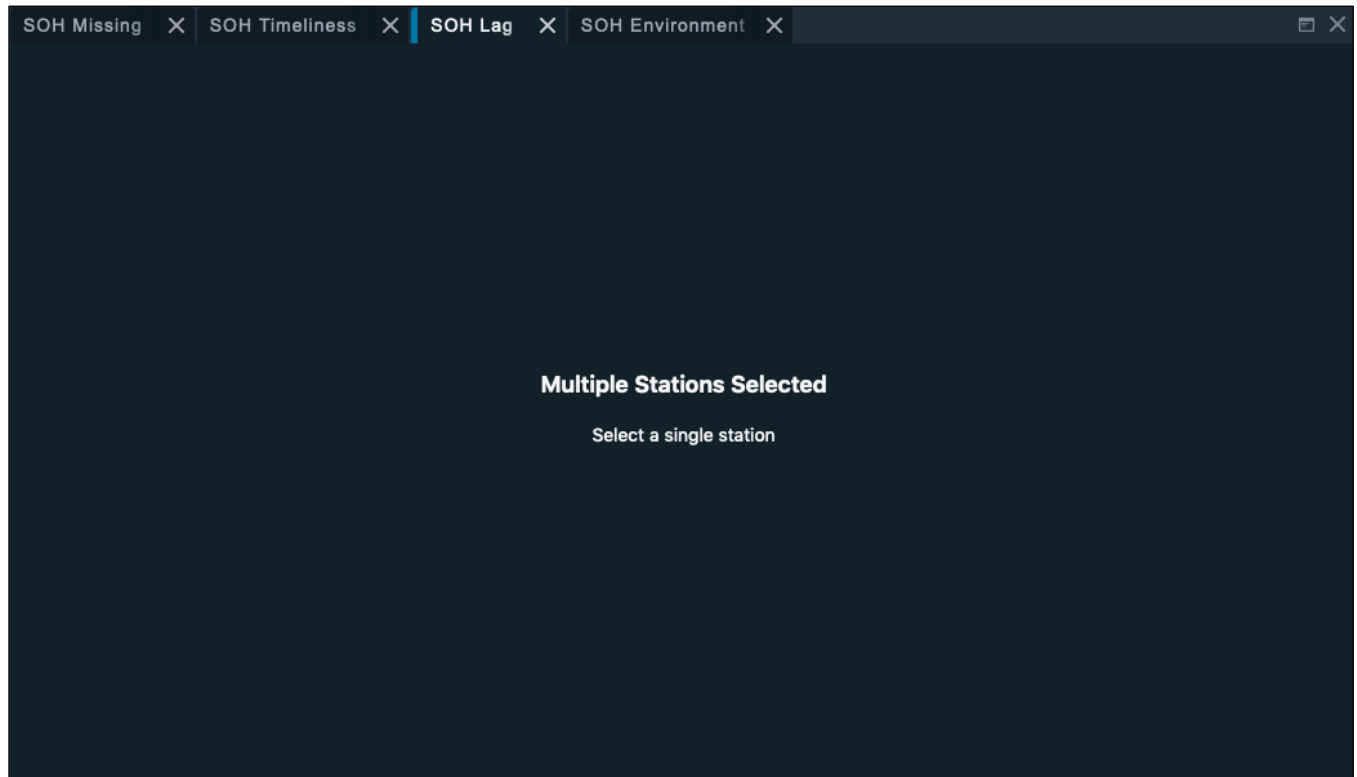
Figure 24. The SOH Lag Display with Multiple Stations Selected.

In the following sections, each drilldown display is described in detail.

5.4.1. SOH Lag Drilldown Display

The SOH Lag drilldown display shows the SOH Lag status of all available channels for a selected station (CMAR in Figure 25).

Figure 25. The SOH Lag Drilldown Display.

Lag (in seconds) is shown on the y-axis and the channel name is shown on the x-axis. Yellow and red horizontal lines indicate marginal and bad thresholds. Vertical bars are colored based on SOH lag status, with green = good, yellow = marginal, and red = bad. Channels not receiving data have no corresponding bar and the name is grayed out. These channels can be configured to have a status of marginal or a special status of None, i.e., the channel does not contribute to the specified SOH status rollup (see Section 7). By default, channels are sorted alphabetically by channel name ascending from left to right. To rearrange channels by different criteria, the user can click the drop-down menu (upper-right dropdown of Figure 25) shown in Figure 26 and select from four options:

1) Lag: highest to lowest – Arranges channels from highest to lowest Lag value from left to right.

2) Lag: lowest to highest – Arranges channels from lowest to highest Lag value from left to right.

3) Channel: A-Z – Arranges channels alphabetically ascending from left to right.

4) Channel: Z-A – Arranges channels alphabetically descending from left to right.
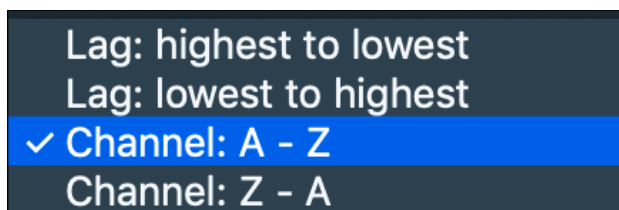
Figure 26. Sorting Options in the SOH Lag Drilldown Display.

When an option is selected, the dropdown button label changes from Channel: A-Z, as shown in Figure 25, to the selected option.

Channels shown in the display are station specific, with broadband 3-component stations only having three channels and station arrays having more than 3 channels (e.g., CMAR in Figure 25). If a station has more channels than can be viewed in the current window, a secondary display will appear beneath the main display as shown in Figure 27.

Figure 27. SOH Lag Display With Secondary Display Shown at Bottom.

The secondary display shows the channels on a modified scale, allowing all available channels to be viewed at once. A white rectangle in Figure 27 indicates which channels are simultaneously being viewed in the secondary display (Figure 27, bottom) and the main display

(Figure 27, top). By default, this rectangle will initially be positioned at the far left of the secondary display. To view other channels, the rectangle can be dragged to a new position.

A new rectangle can be generated at a desired position by clicking a point on the secondary display and holding while dragging the cursor to the right. When the rectangle is the desired width, release the mouse/touchpad to set the new rectangle.

After the rectangle is set and positioned, the user can update its width by hovering over one of the rectangle edges until a double-arrow appears. When the double-arrow is visible, click and hold while dragging the rectangle edge to the desired width. Release the mouse/touchpad to set the new rectangle length. Note that while the rectangle can be modified, it cannot be removed from the secondary display.

The secondary display can be automatically removed by increasing the SOH Lag drilldown display's width until all channels are visible. For station arrays with a large number of channels, e.g., ARCES, the secondary display is always shown.

The height of each vertical bar in the main SOH Lag drilldown display represents a channel's total lag in seconds, with that channel's configurable marginal and bad thresholds (see Configuration documentation) indicated by yellow and red horizontal lines, respectively. A channel's SOH lag status is determined by comparing bar height to these thresholds. To keep the thresholds visible on screen, the maximum y-axis value is set to either the maximum lag value or the maximum threshold value depending on which is larger.

If the channel's bar height is below both the marginal and bad thresholds, the channel's SOH lag status is good, and the bar is green. If the bar height is greater than the marginal threshold but below the bad threshold, the channel's SOH lag status is marginal, and the bar is yellow. If the bar height exceeds the bad threshold, the channel's SOH lag status is bad and the bar is red.

The lag value can be viewed via a tooltip by hovering over the channel name. If no data were received for a channel, the tooltip value will be null.

Each channel's SOH lag status is determined and updated at a configurable Update Interval. This time is in the upper-right corner of the SOH Lag display (Figure 25). Depending on the display width, the user may need to click the colon symbol to view it.

The user can select which channel SOH lag statuses to view by clicking the Filter Status dropdown at the top-left corner of the SOH Lag display and checking all desired statuses (Figure 28).
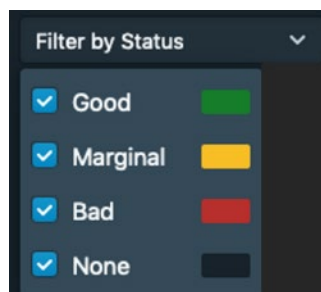
Figure 28. SOH Lag Filter by Status Dropdown Menu.

In the main SOH Lag display, unacknowledged channels are indicated by a white dot next to the channel name (Figure 25). Stations not receiving data are neither considered acknowledged or unacknowledged. They are indicated by a grayed out channel name. When a station is acknowledged in the SOH Overview or Station Statistics display (Section 5.2.1), the channels are placed in a quiet period and the white dots disappear. When this occurs, a clock showing the duration of the quiet period appears at the top of every acknowledged channel's bar, see Figure 29. If a bar is too short to accommodate the clock, the clock is displayed above the corresponding bar.
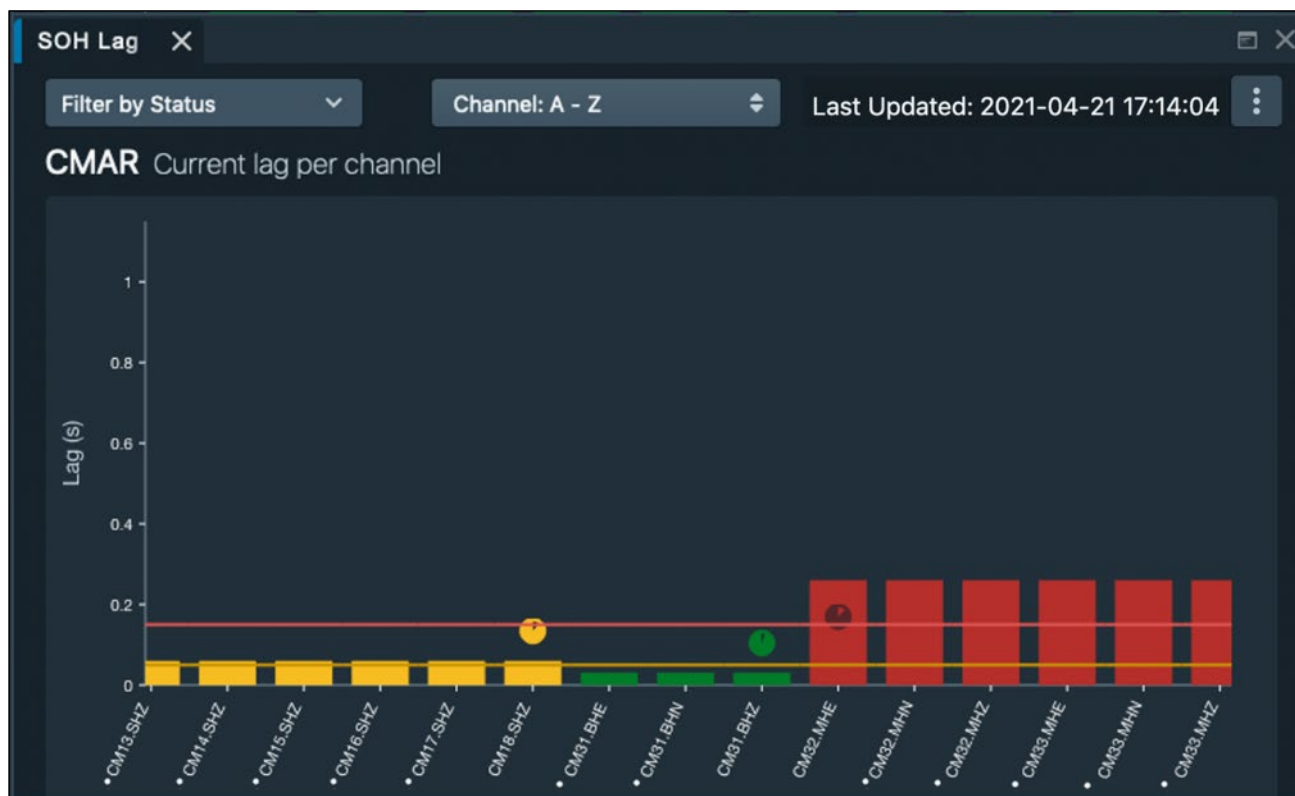
Figure 29. Acknowledged Channels in the SOH Lag Display.

The quiet period's remaining time is indicated by the amount of fill in the clock. The user can hover their cursor over the clock to view a tooltip with the remaining time. All acknowledged channels are automatically placed into a quiet period at the same time; hence their quiet period durations are equal as can be seen in Figure 29. Any changes in the lag status of a channel during this quiet period will result in the station being placed back into Needs Attention after it expires (see Section 5.2.1).

Channels can be manually quieted by right-clicking the bar or channel name and selecting a duration from the option menu. While similar, quieting is not the same as acknowledgement. Quieting will be described in detail in Section 5.4.9.

5.4.2. SOH Lag Trends Drilldown Display

The SOH Lag Trends drilldown display (Figure 30) consists of a bar chart and a time-series plot. It shows lag trends over a specified time range for all available channels of a specific station. This display is not part of the default workspace layout, but can be added by clicking the application level menu button (Figure 3) and selecting SOH Lag Trends from the SOH menu options (Figure 8). See Sections 4 and 5.1 for more detail.

Figure 30. The SOH Lag Trends Drilldown Display.

The bar chart shows the average lag per channel (in seconds) over the specified time range. Each channel's current marginal and bad thresholds (see Configuration documentation) are

shown as yellow and red horizontal lines, respectively. If a channel's average lag exceeds one or both thresholds, the channel is marginal or bad, respectively. Unlike the SOH Lag display, the bar colors do not indicate whether a channel is problematic.

Just as with the SOH Lag drilldown display (Figure 27), a secondary display showing all channels on a modified scale is visible if the number of channels exceeds what can be shown in the main Lag Trends drilldown display. See Section 5.4.1 for details and use.

The time-series plot indicates the change in lag (in seconds) per channel over the same specified time range as the bar chart. By default, all channels' time-series will be shown in the plot with the same colors as in the bar chart. Individual channels can be hidden to improve viewing via the dropdown menu (Figure 31) located in the upper-left corner, see Figure 30. From this menu, a channel's bar chart and time-series can be removed from the display by deselecting it.

Figure 31. Lag Trend Time-Series Filter Dropdown Menu.

Each channel in the Lag Trends drilldown display will have a unique color to ensure the bar and time-series of a specific channel are easily identifiable. Note that this unique channel color will also be used in the Missing Trends, Environment Trends, and Timeliness Trends drilldown displays (see Sections 5.4.4, 5.4.6 and 5.4.8 for these displays).

The user can zoom into a portion of the time-series plot using the cursor shown as a vertical white bar (see Figure 30). To zoom, continuously hold the Ctrl key (Command on Mac) while clicking and dragging the cursor. A white window indicating the new time interval to zoom to will be shown, with the end time of the window printed to screen above the cursor (Figure 32).

Figure 32. Window Indicating Time Interval to Zoom to with Exact End Time Printed to Screen.

Once the desired window length is highlighted, release Ctrl + click. To zoom back out to the original window, double-click the left mouse button. Alternatively, the user can zoom in and out by holding the Ctrl key and scrolling (Command and scroll on Mac). Note that zoom can only be applied a limited number of times. A pop-up message will be displayed in the lower-right corner if the maximum zoom has been reached.

The user can also print a specific time above the cursor on the time series plot without zooming in by clicking and holding the left mouse button only. By dragging the cursor across the screen while continuing to hold the left mouse button, the user can view different specific times in the series.

By default, the time range of the bar chart and time-series plot is set to be the last 6 hours. The user can specify another time range via the drop-down menu shown in Figure 33. The menu is brought up by clicking the edit button in the upper-right corner (see Figure 30). The user can either select a default time range at the left of the menu (last 6 hours, last 12 hours, last 1 day, last 7 days, or last 30 days) or select a start and end date via the calendars and/or dialog boxes below.

Figure 33. Time Range Dropdown Menu.

To set the time range of data to view within the operational time period, the user can either input a start and end time in the Start and End options or select whole days by clicking a start and end date on the calendar. The Start and End options and calendar are synced such that manual entries in the Start and End options will cause the corresponding dates to be highlighted in blue on the calendar, with dates between the start and end dates shown in light gray. Alternatively, selecting a start and end date with the calendar will fill the Start and End options with the corresponding start/end dates and times selected. In either case, note that a warning will be displayed and the Apply button will be grayed out if the start date is set later than the end date.

When entering times into the Start and End options, click the Start and/or End date and type in the desired date in **YYYY-MM-DD** format. If a different format is entered, e.g., 2021:09:12 or 09-12-2021, the date will automatically be converted to the default format. If an invalid date is entered, the value will revert to the last valid value entered. Also, if the end date is set to a time prior to the start date, a warning will be displayed and the Apply button will be grayed out until a valid date is entered. The hour and minute can be set by either clicking on the hour and/or minute box and manually entering in a value or using the up and down hours to increase or decrease the hour/minute, respectively. If an incorrect value is manually entered into the hour/minute box, the box will be highlighted in red. The user must either enter in a new value or click anywhere to have the value revert back to the last valid value entered.

When using the calendar, the user clicks on a desired start date first. This action will cause the date to be highlighted in blue. The user then clicks on another date to set the end time, which is also highlighted in blue. Any dates between the start and end dates are shown in light gray. Note that the same day can be selected as the start and end date by clicking on it twice. To select a new time range, the user can click on another desired start date and repeat the same actions as above.

Once a time range has been chosen, the user clicks the Apply button to apply the new time range to the bar graph and time-series plots. Depending on the display width, the user may need to click a colon symbol to view the history interval, i.e, time range, dropdown menu. Note that the number of available data points displayed in the time-series plot (as seen at the top left of Figure 30) will decrease, i.e., be decimated, for long time ranges to keep the plot readable.

If no data are available during the time range selected, the display will indicate there are no data as shown in Figure 34.
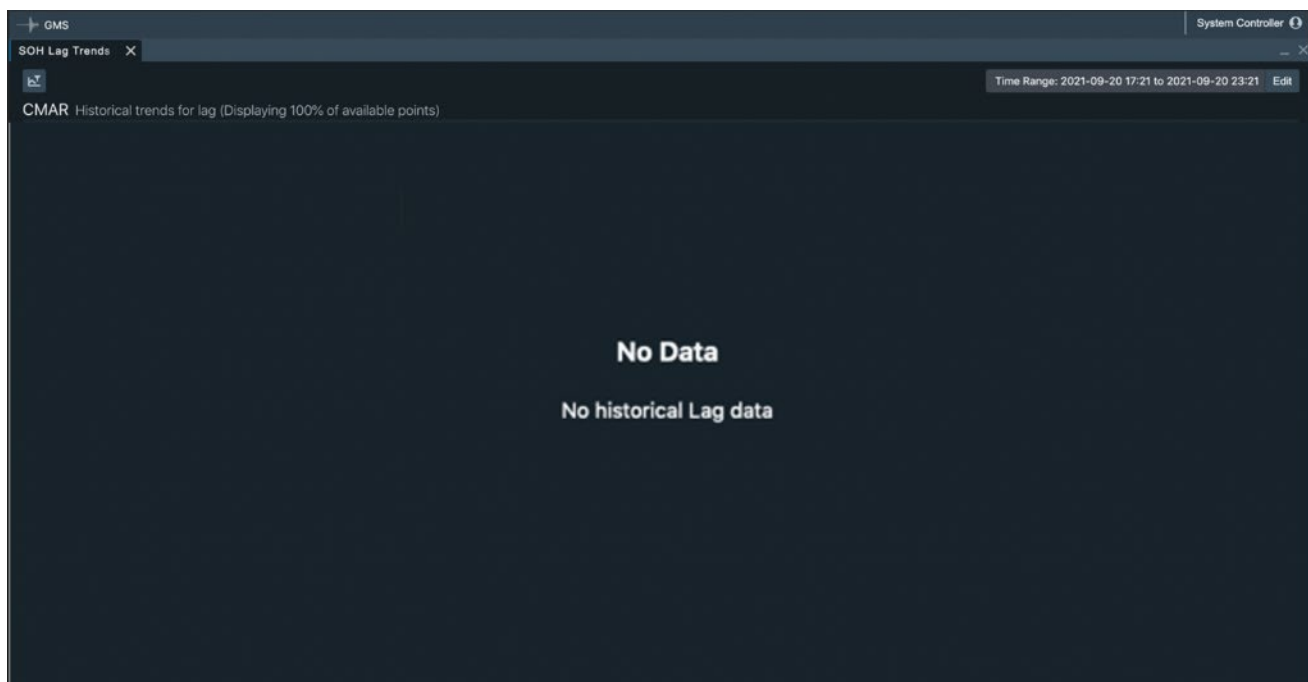
Figure 34. The SOH Lag Trends Drilldown Display with No Data Available.

5.4.3. SOH Missing Drilldown Display

The SOH Missing drilldown display (Figure 35) shows the Missing (%) status of all available channels for a selected station. The bar color indicates a channel's Missing (%) status (green = good, yellow = marginal, and red = bad).
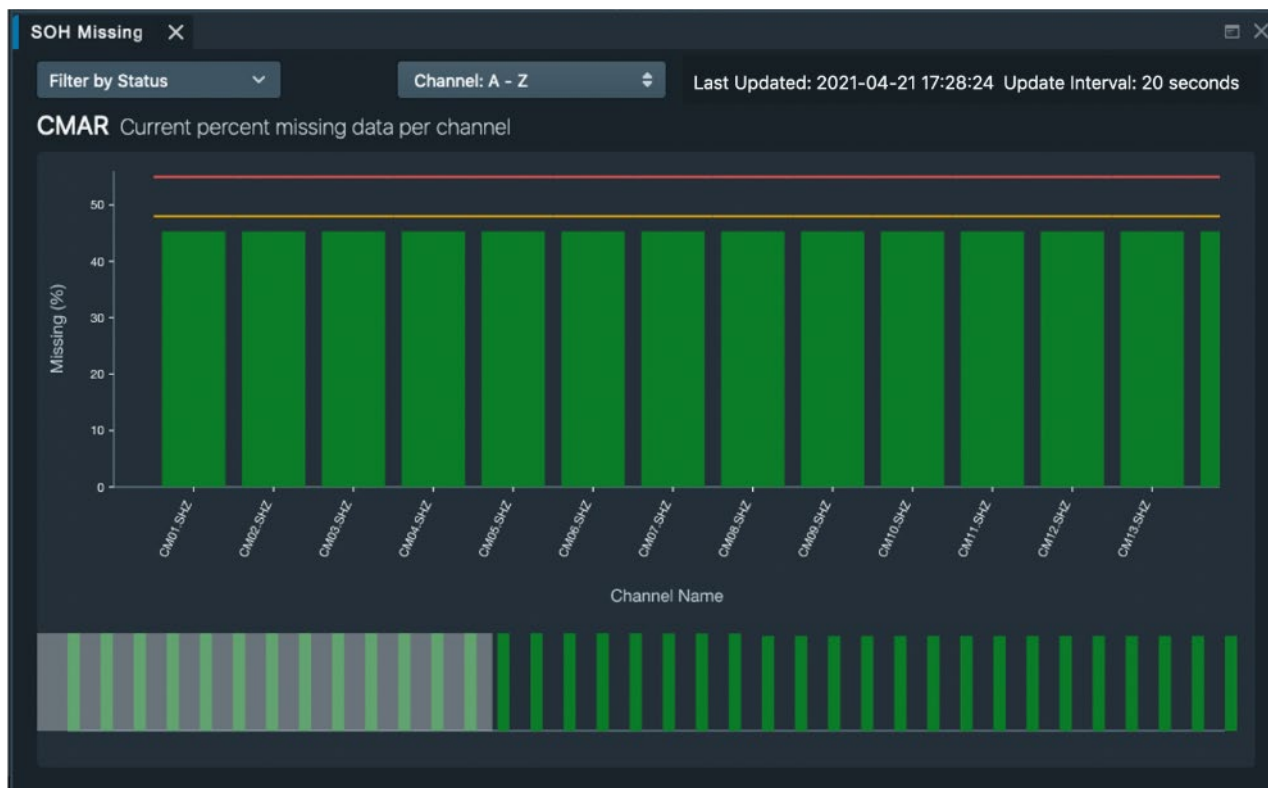
Figure 35. The SOH Missing Drilldown Display.

In the SOH Missing drilldown display, the percentage of missing data (Missing %) is shown on the y-axis, and the channel name is on the x-axis.

The SOH Missing drilldown display functions like the SOH Lag drilldown display; however, it is used for troubleshooting the Missing (%) monitor rather than the Lag monitor. See Section 5.4.1 for display information.

5.4.4. SOH Missing Trends Drilldown Display

The SOH Missing Trends drilldown display (Figure 36) looks and functions like the Lag Trends drilldown display (Figure 30); however, it is used to show the average missing data (%) per channel (bar chart) and the change in missing data (%) per channel (time-series plot) over a specified time range. See Section 5.4.2 for display information.

This display is not part of the default workspace layout and must be added by clicking the application level menu button (Figure 3) and selecting SOH Missing Trends from the SOH menu options (Figure 8). See Sections 4 and 5.1 for more detail.
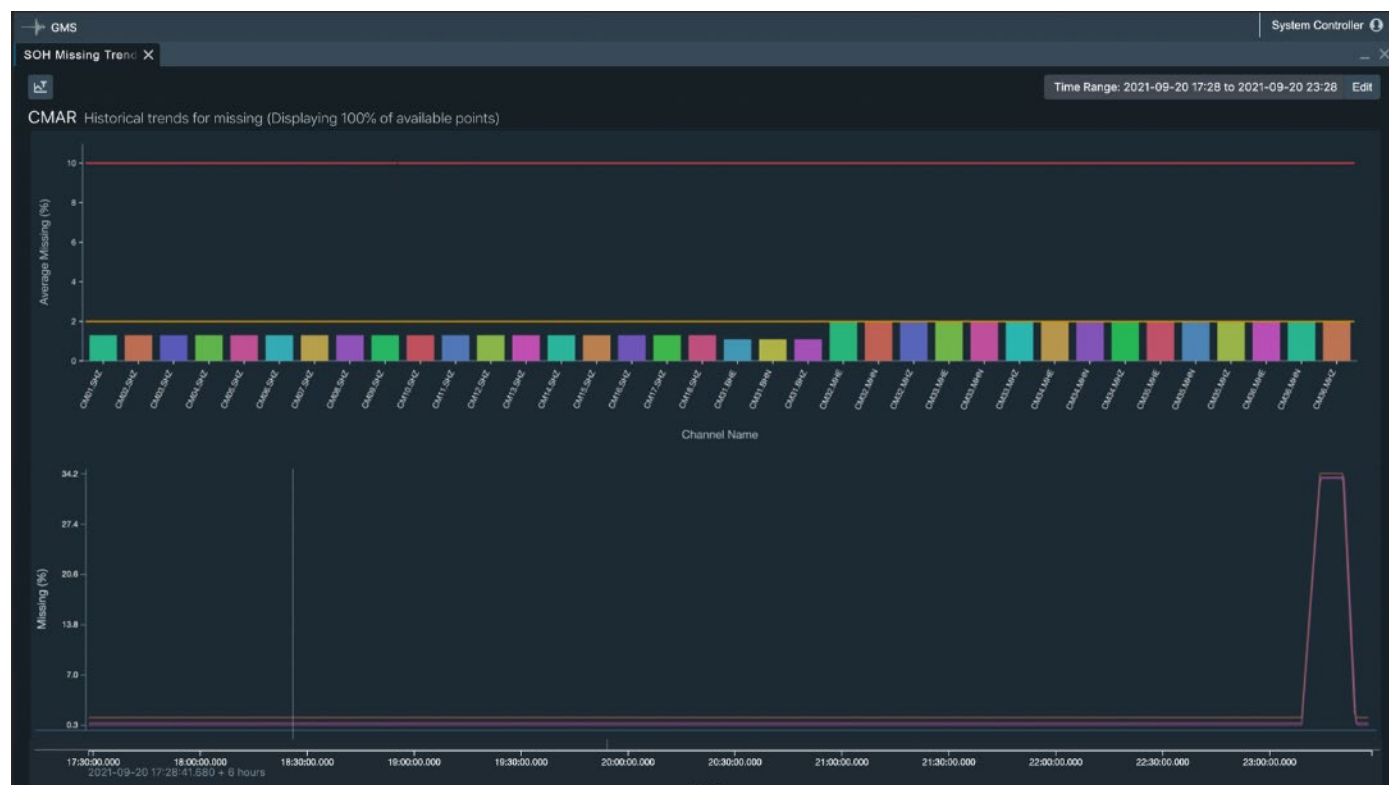

Figure 36. The SOH Missing Trends Drilldown Display.

5.4.5. SOH Environment Drilldown Display

The SOH Environment drilldown display (Figure 37) shows the Environment (%) SOH status of all available channels for a selected station.

Figure 37. The SOH Environment Drilldown Display.

From left to right, the SOH Environment display shows the following information for the specific station shown in the upper-left corner (CMAR in Figure 37):

1) Monitor Type – Lists specific environmental issues and their worst-of SOH status where green = good, yellow = marginal, red = bad, dark gray/hash-marked = no environmental issue data received or the environmental issue was never reported to GMS, and yellow/hash-marked = no data received for an environmental issue that previously received environmental data. The hash-marked monitor type color indicates whether that monitor type contributes to SOH status calculations; yellow/hash-marked will contribute whereas dark gray/hash-marked will not. A list of monitor types is provided at the end of this document.

2) Channels – The remaining columns show the environmental issues data value and SOH status of each monitor type for each channel (CM01.SHZ, CM02.SHZ, CM03.SHZ, etc. in Figure 37), where gray = good, yellow = marginal, red = bad, dark gray/hash marked = no data received or the environmental issue was never reported to GMS, and yellow/hash-marked = no data received for an environmental issue that previously

received environmental data. The color of a hash-marked environmental channel/monitor type pair indicates whether the data value for that pair contributes to SOH status calculations.

The channel's worst-of Environment (%) SOH status is shown by the channel name's color with green = good, yellow = marginal, red = bad, dark gray/hash-marked = no environmental issue data, and yellow/hash-marked = no data received for a channel that previously received environmental data. The color of a hash-marked channel indicates whether that channel contributes to the calculation of SOH status.

Similar to the Station Statistics display in Section 5.3, the percentage of environmental issues for a specific monitor type is shown by the percentage of cell fill as well as by a numerical percentage value (e.g., Figure 38). The percentage of cell fill should match the numerical value written on top.

Figure 38. Percentage of Environmental Issues.

The user has two filter options: Filter Monitors by Status and Filter Channels by Status. These are accessed through dropdowns in the top-left corner of the display. Monitors or channels can be filtered by status in the dropdown menus by checking the desired statuses (see Figure 28).

Unacknowledged channel/monitor type pairs are indicated by a black or white dot to the left of the percentage environmental issue value. For example, the monitor type Authentication Seal Broken has not been acknowledged for channel CM01.SHZ in Figure 37 as indicated by the white dot to the left of its percentage value of 0.00. The different dot colors are for visual ease and do not indicate any channel/monitor status.

When stations are acknowledged in the SOH Overview or Station Statistics display, their newly acknowledged channels are placed in a quiet period and the white/black dots disappear. At this time, a clock indicating the duration of the quiet period appears to the left of the acknowledged environmental issue value, see Figure 39.

Figure 39. An Acknowledged Channel/Monitor Type Pair in the SOH Environment Display.

As in the SOH Lag drilldown display, the quiet period's remaining time is indicated by the amount of fill in the clock; it can also be viewed via a tooltip by hovering the cursor over the clock. Any changes in a channel's environmental issues during this quiet period will result in the station being placed back into the Needs Attention category after the quiet period expires (see Section 5.2.1).

One or more of a channel's environmental issues can be manually quieted by right-clicking the cell(s) corresponding to the channel/environmental issue and selecting a duration from the option menu. While similar, quieting is not the same as acknowledgement. Quieting will be described in detail in Section 5.4.9.

The SOH Environment display shown in Figure 37 is the default layout. In addition to the layout options described in Section 4, the SOH Environment drilldown display can be modified using the layout options described in Section 5.3.1, with the exception that columns cannot be removed from the Environment display.

5.4.6. Environment Trends Drilldown Display

The SOH Environment Trends drilldown display (Figure **40**) shows the raw data for a selected environmental monitor type for all available channels over a chosen period of time. This display is not part of the default workspace layout, but can be added by clicking the application level menu button (Figure 3) and selecting SOH Environment Trends from the SOH menu options (Figure 8). See Sections 4 and 5.1 for more detail.
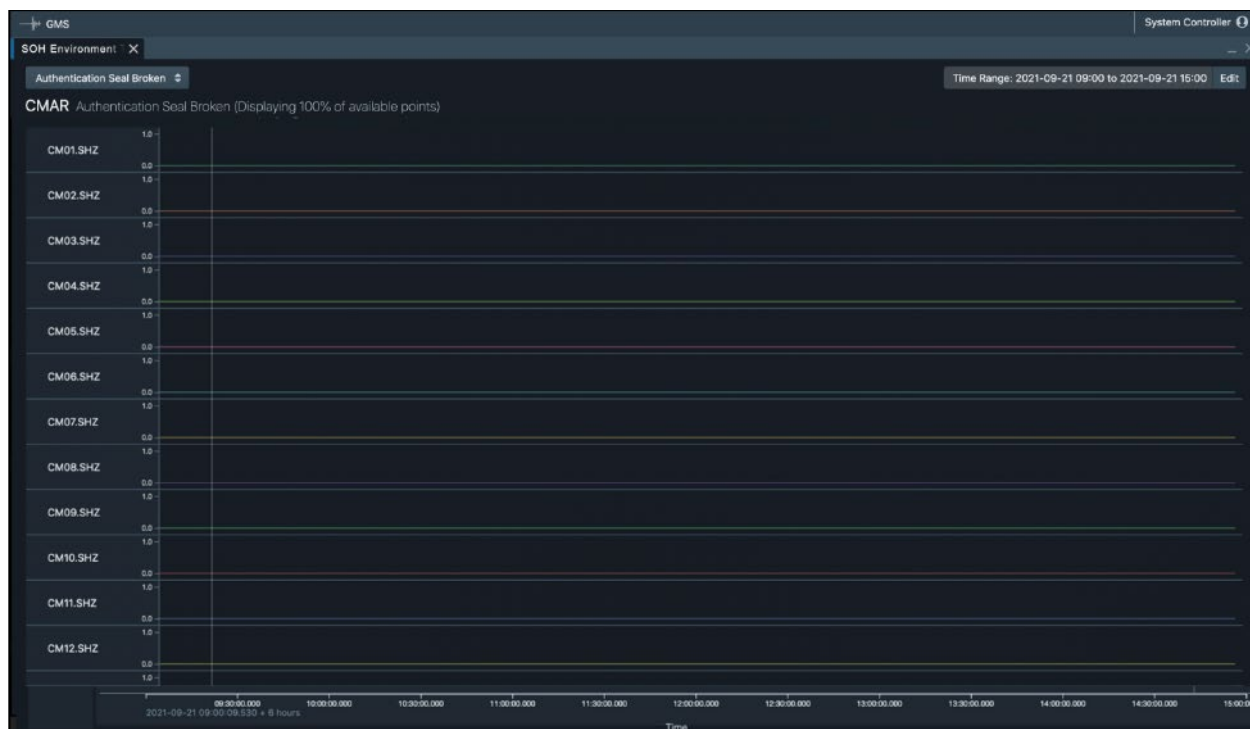
Figure 40**. The SOH Environment Trends Drilldown Display.**

Like other drilldown displays, a station must be selected from the SOH Overview or Station Statistics display prior to viewing information in the SOH Environment Trends drilldown display. However, to populate the Environment Trends drilldown display, a monitor type must be selected in addition to a station. The user can either select a monitor type from the Monitor Type column in the SOH Environment drilldown display (Figure 37) or select a monitor type from the dropdown menu (Figure 41) in the upper-left corner of Figure **40**.
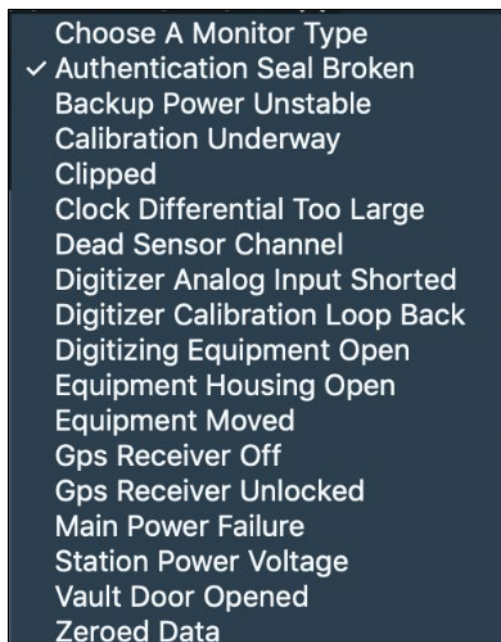
Figure 41. Monitor Type Dropdown Menu.

If no monitor type is selected, the user will be prompted to choose a monitor type (Figure 42).
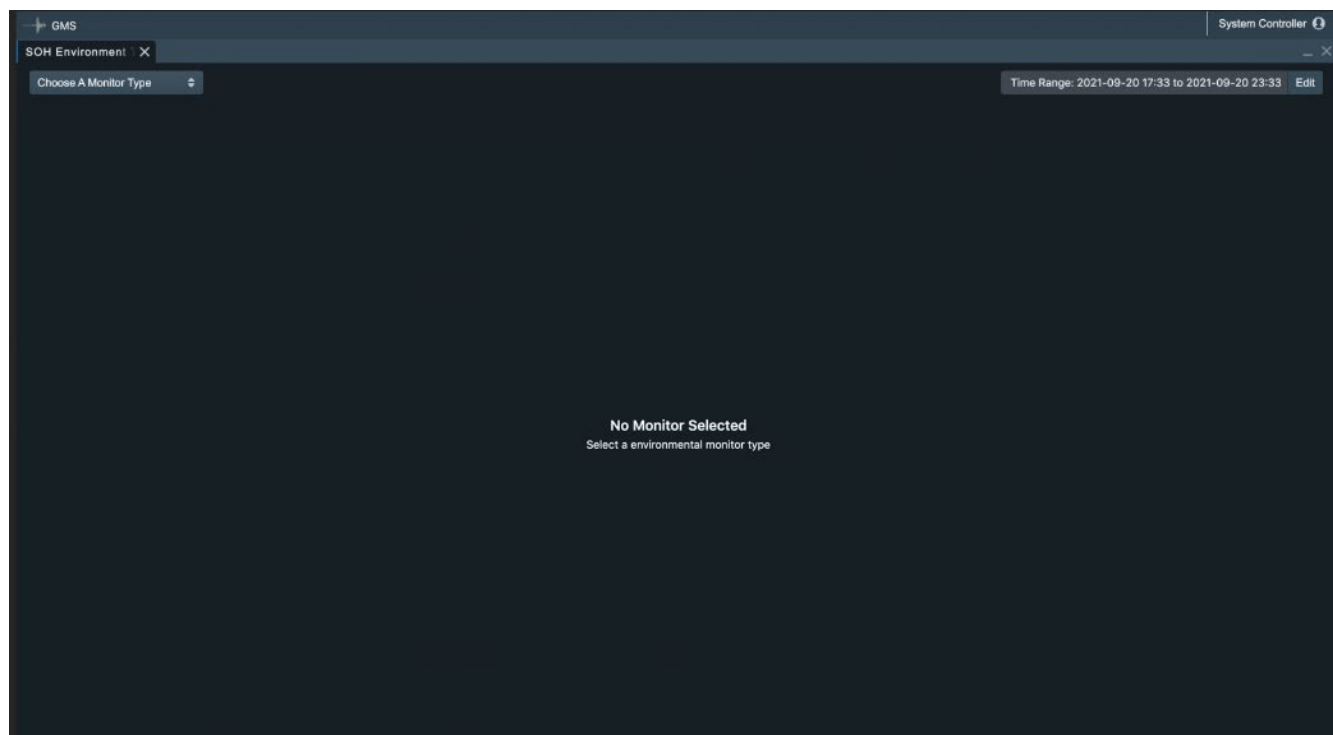
Figure 42. The SOH Environment Trends Drilldown Display with No Monitor Selected.

Currently, the only raw data type being reported in the historical trend interface for channel/monitor pairs are Boolean data. For example, the Vault Door Open monitor type will only report 1 or 0, i.e., the door was open or the door was closed. The Boolean data plots will appear as square waves, with the y-axis having a value of either 0 or 1 and the x-axis representing the time. The total time period shown in the window is indicated at the bottom-left and in the start and end time boxes in the upper right. In Figure **40**, the time period shown is 2021-09-21 09:00:09.530 + 6 hours.

The user can zoom into a portion of the Enviroment Trends drilldown display using the cursor shown as a vertical white bar (see Figure **40**). To zoom, continuously holding the Ctrl key (Command on Mac) while clicking and dragging the cursor. To zoom back out to the original window, double-click the left mouse button. Alternatively, the user can zoom in and out by holding the Ctrl key and scrolling (Command and scroll on Mac). Note that zoom can only be applied a certain number of times. A pop-up message will be displayed in the lower-right corner if the maximum zoom has been reached.

Like the other Trends displays, the user can print a specific time above the cursor on the time series plot by clicking and holding (see Section 5.4.2, Figure 32).

The square wave's height indicates whether the raw data were in a good state (square wave = 0) or a bad state (square wave = 1). The square wave's length indicates the percentage of time that the channel/monitor pair were in that state. For example, if the Vault Door Open monitor type for Channel CM01.SHZ was in a bad state for 18.33% of the past 24 hours, the plotted square wave would show a value of 1 for 18.33% of that time period.

If a channel/monitor pair remains in a bad state longer than the configurable threshold, that channel/monitor pair will have a marginal or bad SOH status depending on configuration, see Configuration documentation. For example, the Channel/Monitor Type pair CM01.SHZ/Vault Door Open can be configured to take on a marginal status when the raw data value = 1 for more than 50% of the past 24 hours.

Selecting a time range to view in the Environment Trends drilldown display is done the same way as the prior two trend drilldown displays, see Section 5.4.2 and Figure 33. Note that there is no channel filter available, unlike other trends drilldown displays (see Figure 31). All channels will always be shown in the Environmental Trends display.

5.4.7. SOH Timeliness Drilldown Display

The SOH Timeliness drilldown display (Figure 43) shows the timeliness status of all available channels for a selected station. The bar color indicates a channel's timeliness status (green = good, yellow = marginal, and red = bad).
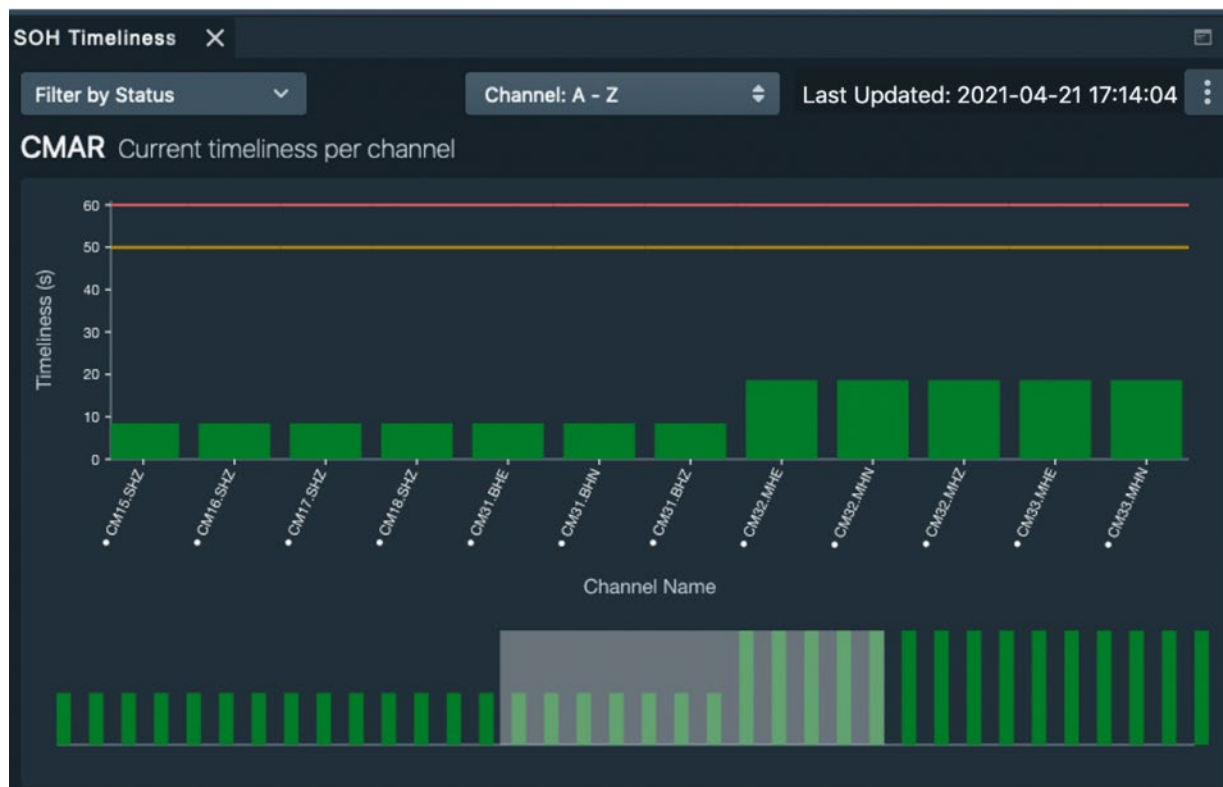
Figure 43. The SOH Timeliness Drilldown Display.

In the SOH Timeliness drilldown display, the timeliness is shown on the y-axis in seconds. The channel name is on the x-axis.

The SOH Timeliness drilldown display functions like the SOH Lag drilldown display; however, it is used for troubleshooting the Timeliness monitor rather than the Lag monitor. See Section 5.4.1 for display information. This display is not part of the default workspace layout, but can be added by clicking the application level menu button (Figure 3) and selecting SOH Timeliness from the SOH menu options (Figure 8). See Sections 4 and 5.1 for more detail.

5.4.8. Timeliness Trends Drilldown Display

The SOH Timeliness Trends drilldown display (Figure 44) looks and functions like the Lag Trends drilldown display (Figure 30); however, it is used to show the average timeliness per channel

(bar chart) and the change in timeliness per channel (time-series plot) over a specified time range. See Section 5.4.2 for display information.

This display is not part of the default workspace layout and must be added by clicking the application level menu button (Figure 3) and selecting SOH Timeliness Trends from the SOH menu options (Figure 8). See Sections 4 and 5.1 for more detail.


Figure 44. The SOH Timeliness Trends Drilldown Display.

5.4.9. Quieting

In the SOH Lag, Missing, and Environmental drilldown displays, the user can manually quiet individual channels/monitors. When a channel/monitor is quieted, the user will not be notified of any changes in SOH status during the quiet period. This prevents a user from being repeatedly notified of a station with issues that can't be fixed quickly.
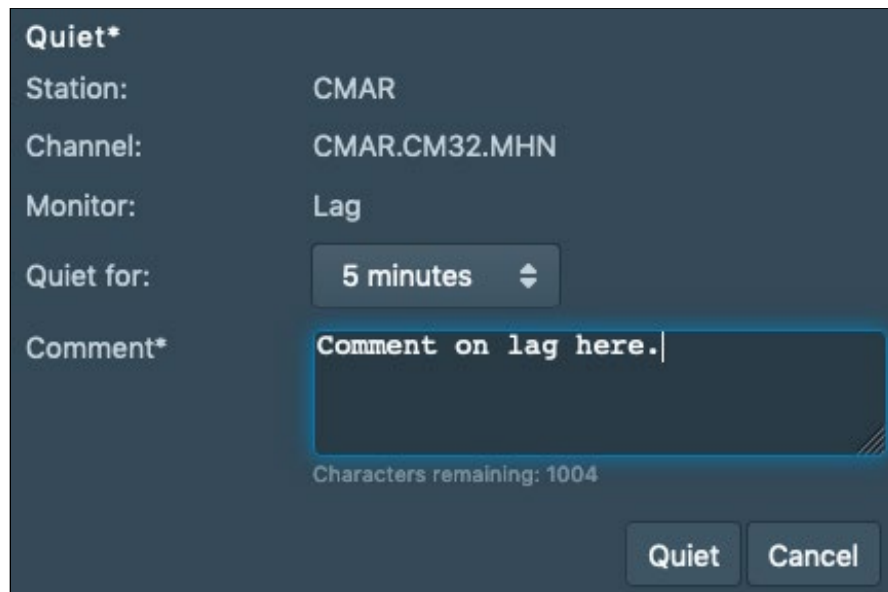
To quiet a channel/monitor pair, the user right-clicks a channel's corresponding bar/channel name (SOH Lag and Missing drilldown displays) or a specific channel/environmental monitor type pair (Environmental drilldown display) to bring up the option menu for quieting shown in Figure 45. Multiple channel/environmental monitor type pairs can be quieted in the Environmental drilldown display by holding the Ctrl key (Command on Mac) while clicking on the desired channel/monitor pair, then right-clicking one of the selected pairs to bring up the menu (see Figure 45).
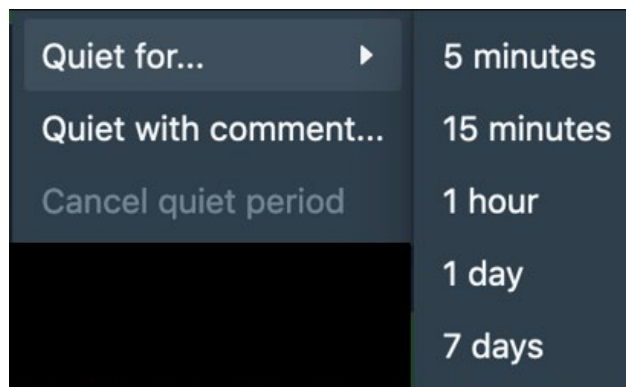
Figure 45. Quieting Option Menu.

The user can then select the quiet period's duration or cancel a quiet period if a channel/monitor pair has already been quieted. Available quiet period durations are 5 min, 15 min, 1 hr, 1 day, and 7 days. The list of available quiet period durations is configurable (see Configuration documentation).

The user can also write an associated comment when quieting one or more channel/monitor pairs by selecting the Quiet With Comment option. This action will bring up the text area shown in Figure 46.

Figure 46. Text Area to Add Comment to Quieted Station.

In the text area, the user can enter a message with a 1024 character limit. The number of characters remaining is beneath the text area. Once a quiet period duration and comment are entered, the user selects the Quiet button and the channel/monitor pair is quieted. The related comment is stored in a database with the station, channel(s), monitor type(s), comment timestamp, and the username for provenance. This comment information is made viewable in the System Message display (Section 5.6).

The user can manually overwrite or cancel a previously applied quiet period by right-clicking the quieted channel's bar or specific environmental issue and selecting either a new quiet period duration or canceling the quiet period; this can be done regardless of whether the previous quiet period was applied manually or automatically by acknowledgement (Section 5.2.1). An automatic quiet period applied by acknowledgement in the SOH Overview or Station Statistics displays will not overwrite any previous manually applied quiet periods.

Once quieted, a clock symbol showing the quiet period's duration appears at the top of a quieted channel's bar (Lag, Missing, and Timeliness drilldowns) or to the left of a quieted channel's percentage environmental issue value (Environmental drilldown). Because these manual quiet periods are individually applied rather than automatically applied by acknowledgement, each quiet period may differ in duration, see Figure 47. A user can view the time left within each unique quiet period by hovering over the clock symbol. The clock's remaining fill should match the written time.
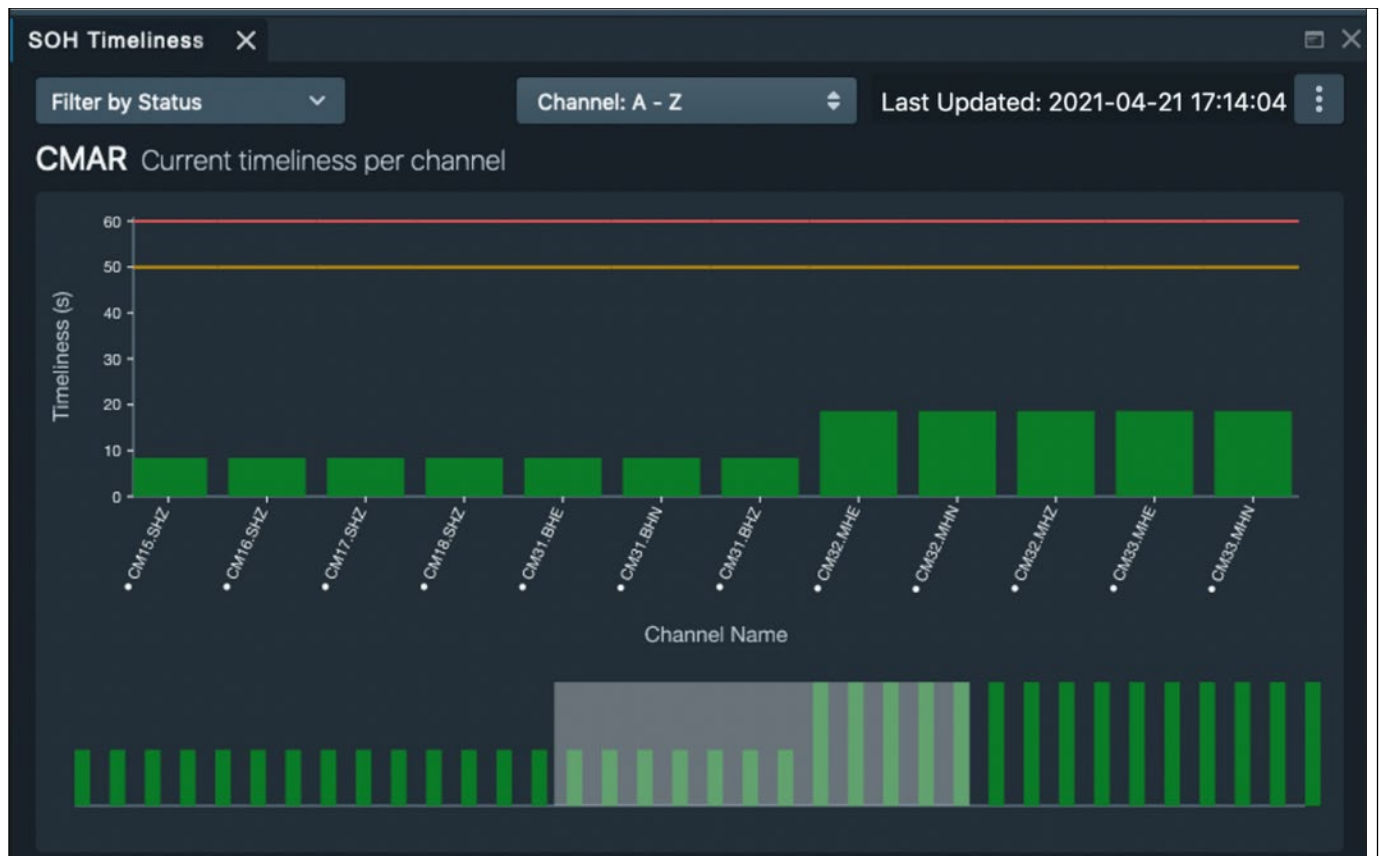
Figure 47. Manually Quieted Channels in the SOH Lag Drilldown Display.

Following the quiet period's expiration, the user is notified of any changes in general SOH status that arose during or after the quiet period as well as any unacknowledged changes that existed prior to quieting.

Manually quieted individual channels/monitors are not acknowledged. As shown in Figure 47, the white dot in front of the channel name indicates it has not been acknowledged. If a user manually quiets one or more channels/monitors and places that station in the unlabeled category indicating acknowledgement, the station will be placed back into Needs Attention when the manually applied quiet periods expire or are cancelled, regardless of the remaining time in the automatic quiet periods applied by acknowledgement.

However, it is possible to use manual quieting to acknowledge a station's general SOH status by quieting every unacknowledged channel/monitor in all four drilldown displays. When this is done, the station is placed in the unlabeled category indicating acknowledgement in the SOH Overview and Station Statistics displays automatically; however, once these quiet periods expire, the station will be placed into Needs Attention.

5.5. SOH Map Display

The SOH Map display (Figure 48) provides a map showing station locations, where each station is represented as a triangle. If zoomed in sufficiently, the station name will appear next to the corresponding station marker.
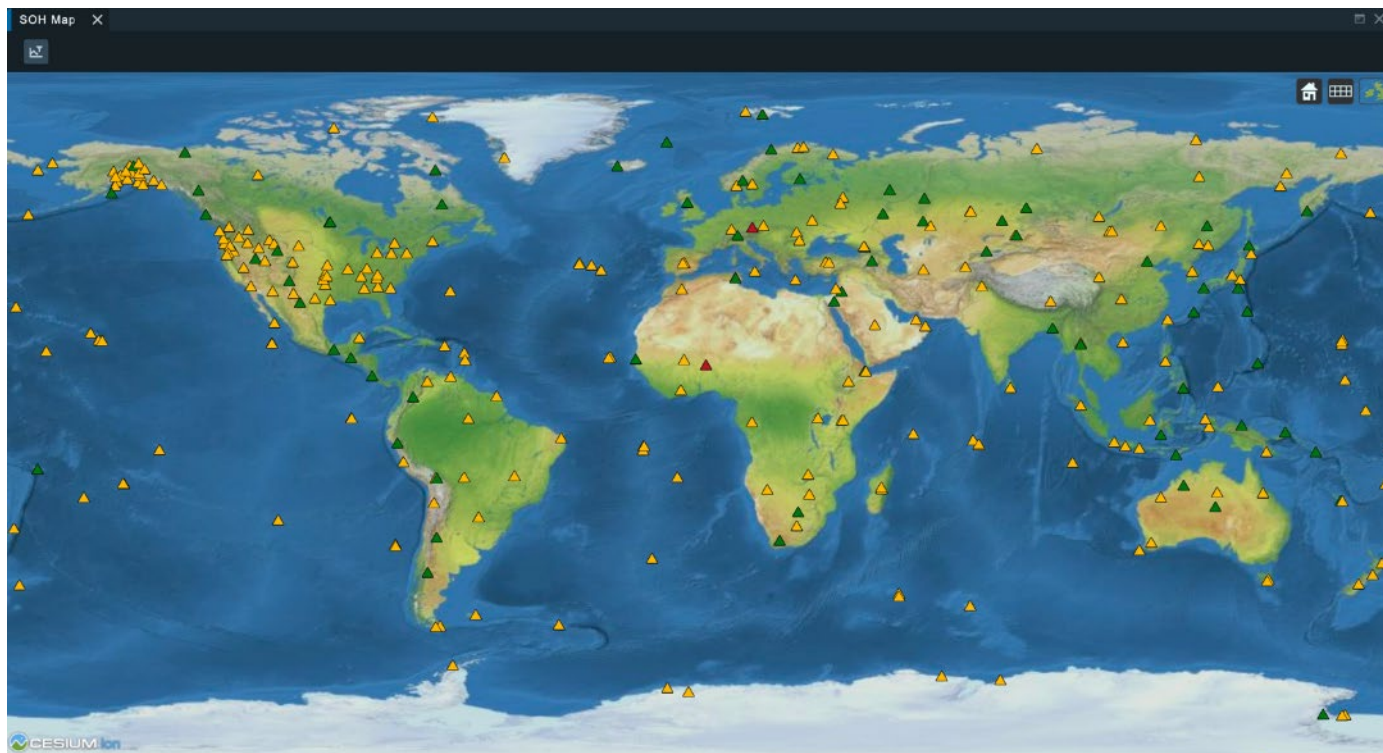
Figure 48. SOH Map Display.

By default, all stations from all groups are shown on a 2D projection, with station color indicating a station's current worst-of SOH status (green = good, yellow = marginal, and red = bad). In this default projection, the user can click and drag to pan across the map. The user can also zoom in and out by 1) using the mouse scroll wheel (scroll forward to zoom in, scroll back to zoom out) or 2) using a two-finger drag on a touch pad (drag towards the user to zoom in, drag away from the user push away from the user to zoom out). Also, the user can zoom in to a single station by double-clicking on that station.

To select a particular station group(s) for viewing, click on the button in the upper-left corner to bring up the dropdown menu in Figure 49.
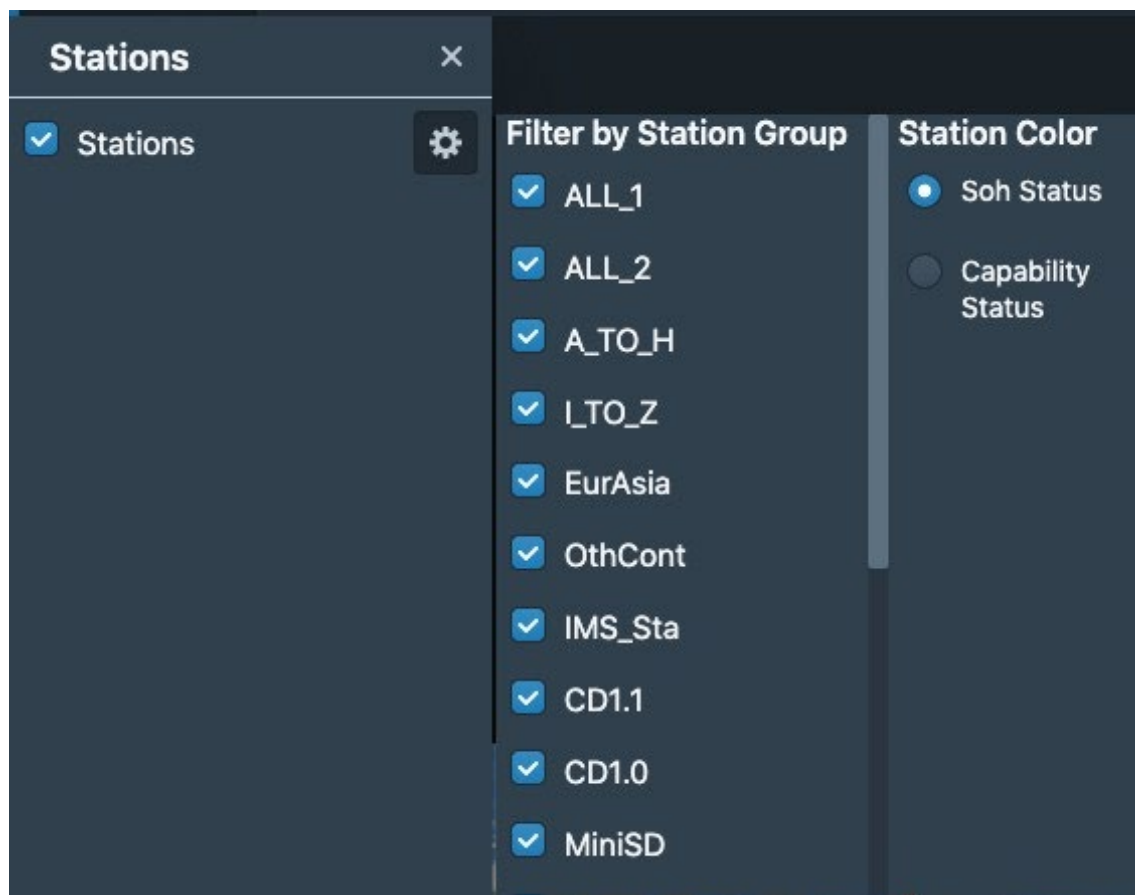
Figure 49. Map Stations Dropdown Menu With Options Menu Open.

In this menu, the user can choose to turn off all stations by deselecting the Stations option. To select/deselect certain station groups, the user should click the gear wheel to the right of Stations. This action will bring up a list of all station groups, which the user can select/deselect for viewing. Since the worst-of SOH status does not vary among station groups (Section 5.3), station color will not change with group selection.

The user can also have the map display capability-based status instead of worst-of SOH status (called Soh Status in Figure 49) by selecting Capability Status. If capability-based status is shown on the map while multiple groups are selected, a station's color will indicate its worst capability-based status among all selected groups. As with worst-of status, green = good, yellow = marginal, and red = bad. In addition, stations can also have a special None capability-based status (see Section 5.2.1 for details). In this case, station markers will be black as show in Figure 50.
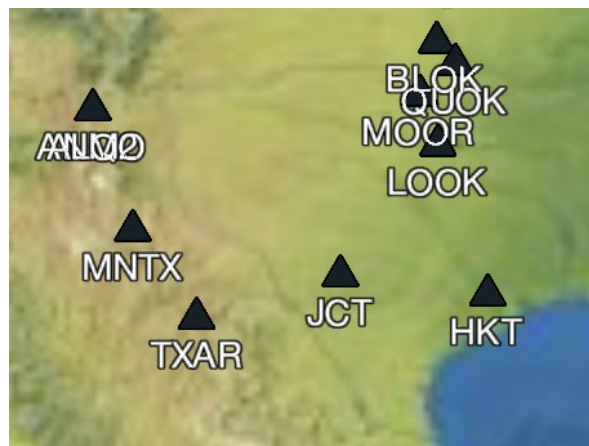
Figure 50. Map Markers with a Capability-Based Status of None.

The Map display is synced to the SOH Overview and Statistics displays (Sections 5.2, 5.3) such that when a station is selected in the Map display, that station will be highlighted in blue in all three displays (Figure 51).
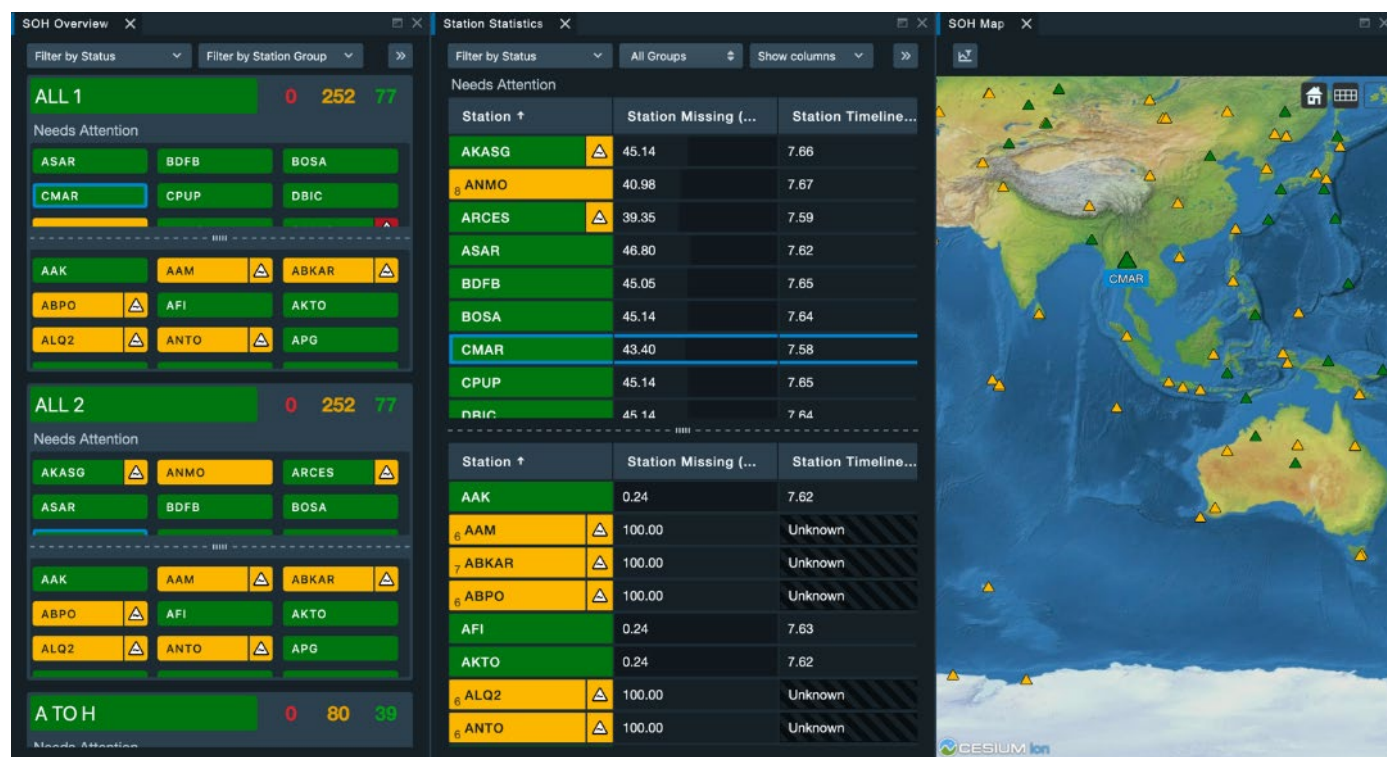
Figure 51. The SOH Overview, Station Statistics, and SOH Map Displays With Station CMAR Selected.

In addition, a selected station's marker will appear larger than other markers as seen in Figure 51. Note that acknowledgement (Section 5.2.1) and quieting (Section 5.4.9) cannot be performed in the Map display.

Three other buttons are provided in the upper-right corner of the Map display (Figure 48) as shown in Figure 52.

Figure 52. Map Display Buttons.

From left to right, the buttons are the View Home button, Projection button, and Imagery and Terrain button. Hovering over a button with the cursor will write provide a tooltip briefly describing that button.

When the user clicks the View Home button, the map will automatically be positioned over the United States regardless of starting position. Note that if the map is already optimally positioned over the United States, clicking on the View Home button will result in no change.

When the user clicks the Projection button, a dropdown menu with alternative projections is provided (Figure 53, left). Hovering the cursor over each option in the dropdown menu will provide a tooltip briefly describing the projection. Currently, in addition to the default 2D projection, a 3D globe (Figure 53, center) and a tilted projection known as a Columbus projection (Figure 53, right) are provided.

In the 3D globe projection, click and drag to rotate the sphere; to zoom, perform the same actions described for the default 2D projection. In the Columbus projection, the actions to pan and zoom are identical to the 2D projection.
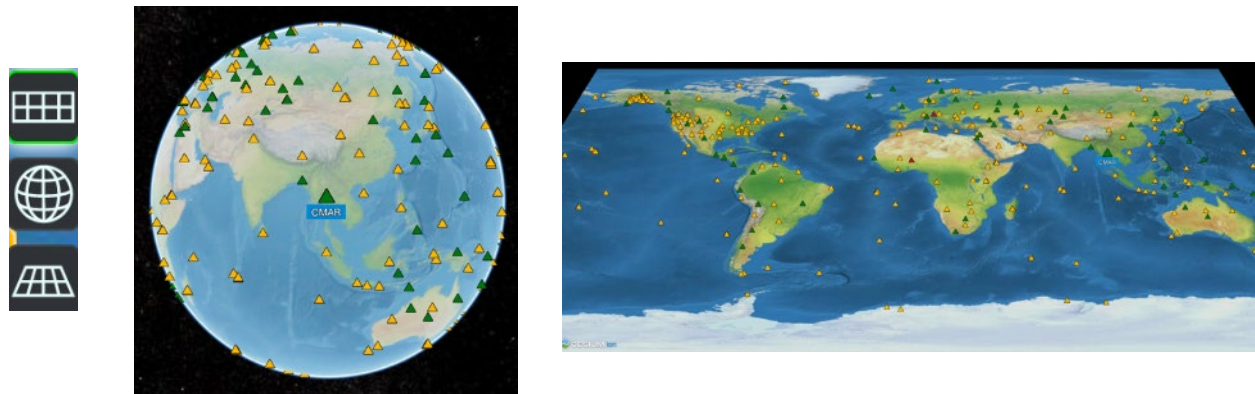
Figure 53. Projection Dropdown Menu (Left), 3D Globe Projection (Center), Columbus Projection (Right).

When a projection option is selected, the Projection button label changes to the current projection being viewed.

The Imagery and Terrain button provides a dropdown menu (Figure 54) allowing the user to select the appearance of the map and the ellipsoid to be used to define the terrain.
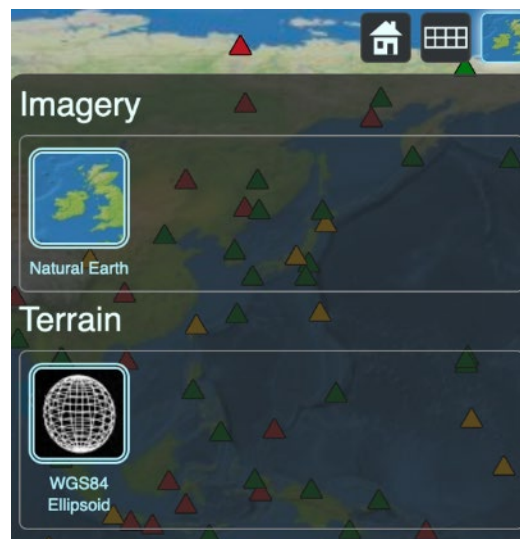
Figure 54. Imagery and Terrain Dropdown Menu.

Currently, only default options are provided for imagery and terrain (see Section 8). These defaults are automatically applied to the map and cannot be changed or removed.

5.6. System Messages Display

The System Messages display (Figure 55) provides a scrolling list of messages output by the system in real time.

Figure 55. The System Messages Display.

By default, messages are sorted by timestamp with the latest message at the end of the list. The list scrolls continuously, making the latest message visible when the Auto Scroll option (upper-right corner of Figure 55) is enabled (white dot to the right). To pause scrolling for easier viewing, the user can toggle the Auto Scroll off (white dot to left). Auto scrolling will also automatically pause if the user scrolls up or changes pages; new messages received during this time will be indicated by a new message icon at the bottom of the window (e.g., Figure 55). The user can also select the Clear list button to clear current messages from the window.

The messages shown in this display can result from a station needing attention (Sections 5.2 and 5.2.1), changes to station or channel/monitor SOH status (Section 7.1), changes to station or station group capability-based rollup status (Section 7.2), the acknowledgement or quieting of a channel/monitor pair (Sections 5.2.1, 5.4.9), or the cancellation or expiration of a quiet period (Section 5.4.9).

From left to right, each row of the System Messages display shows the following information:

1) Timestamp – The date and time a message was created.

2) Category – A category indicating what part of the GMS system caused the message, (e.g., SOH, FK analysis). Currently, SOH is the only available category.

3) Subcategory – A subcategory indicating whether the message resulted from a change in station SOH status (Station), a change in capability-based rollup status (Capability), or from a user action such as acknowledgement (User).

4) Severity – Indicates the severity of the issue reported in the message; the three categories from least to most severe are Info, Warning, and Critical.

5) Message – The system message string for the respective message type. Hover over the Message column to view the full system message via a tooltip.

Each message color is based on its reported severity: informational messages are dark gray, warning messages are yellow, and critical messages are red. The number of messages in each category is shown in the upper-left corner, see Figure 55. By clicking on a number category the user can filter messages by severity. For example, if the user clicks on INFO: 16 in Figure 55, informational messages will no longer be shown. To remove the filter, click on the same number category again, e.g., INFO: 16 in this example. Note that the colors are configurable (see Configuration documentation).
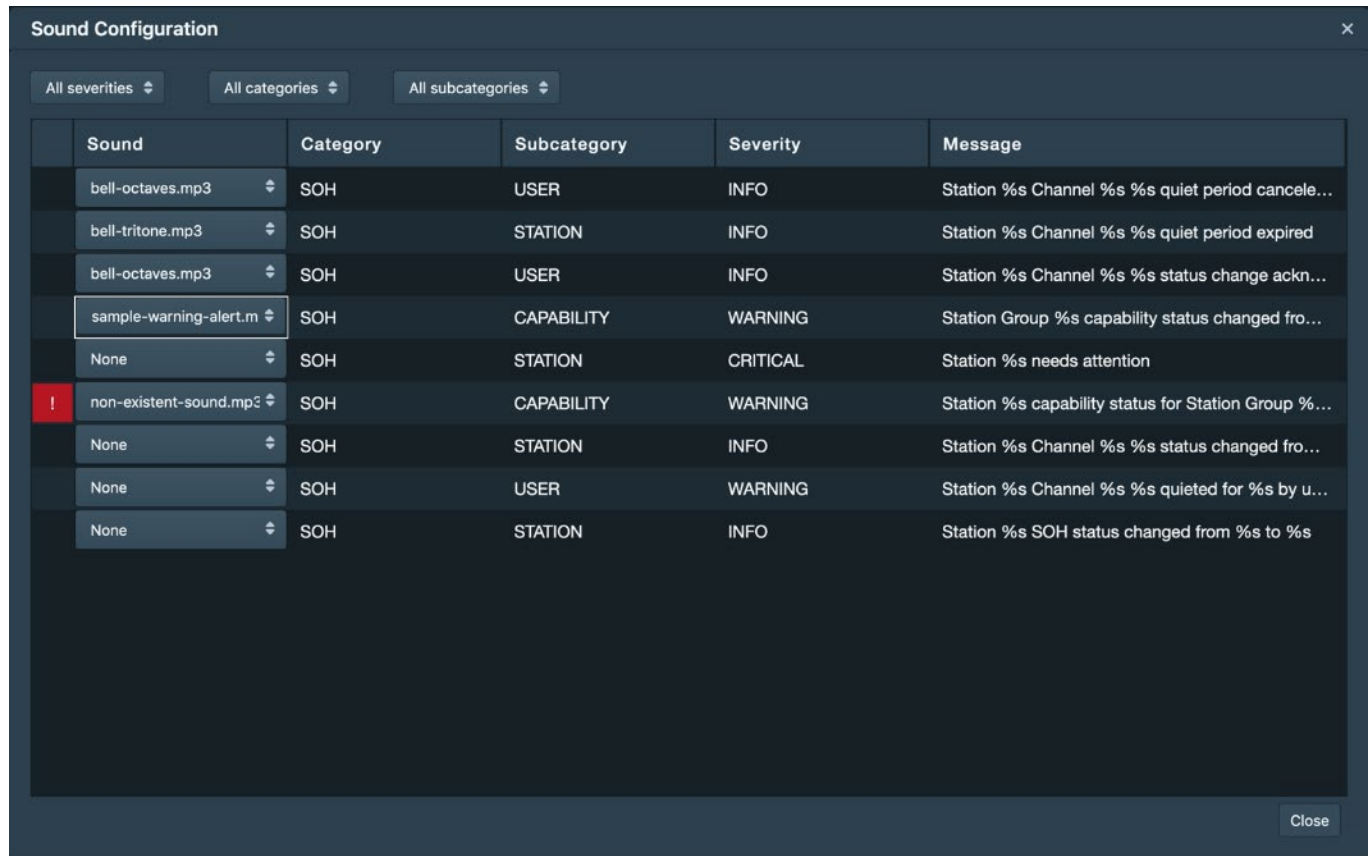
- Informational messages indicate the general SOH status of a station or channel/monitor pair has changed, a channel/monitor quiet period has expired or been cancelled, or a user has acknowledged a channel/monitor pair status change (with or without a comment).

- Warning messages indicate a change in station or station group capability-based rollup status, or a user has quieted a channel/monitor pair (with or without a comment).

- Critical messages indicate a station needs attention.

A table of message types and their corresponding severities, categories, and sub-categories is provided at the end of this document. Note that the user cannot modify the available message types or their categorizations.

The System Messages display in Figure 55 shows the default layout. In addition to the layout options described in Section 4, the System Messages display can be modified in the same ways as the Station Statistics display, with the exception that columns cannot be removed (see Section 5.3.1).

Incoming messages can be assigned unique audible notifications by clicking on the Configure sounds button in the upper corner (see Figure 55) to bring up the menu shown in Figure 56.

Figure 56. Sound Configuration Menu.

Each row of the sound configuration menu represents a system message type that can be received in the System Messages display (see System Message Definitions at end of document for full list of types). System message types can be filtered based on severity, category, or subcategory using one of the three drop-down menus in the upper left (see Figure 56).

The Sound column on the left (Figure 56) provides a drop-down list of available sounds that the user can select an audible notification for each message type. The list of available sounds can be modified but not in the Sound Configuration menu (see Configuration documentation). If a configured sound fails to load, the user will be notified via a warning message in the lower-right corner of the SOH UI (Figure 57).
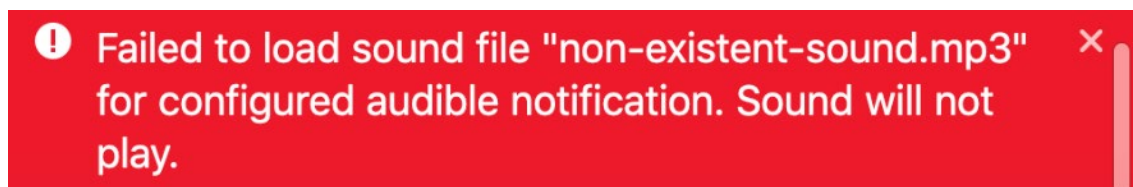
Figure 57. Failed to Load Sound Warning Message.

In addition, a red exclamation point will appear left of the sound that failed to load (see Figure 56).

When a sound is first selected from the drop-down list, the sound will automatically play. The same audible notification can be assigned to more than one message type (e.g., bell-octaves.mp3 in Figure 56). Once done, the user can close the Sound Configuration window by clicking Close at the bottom right or the x symbol at the top right (see Figure 56). The newly configured sounds can be muted/unmuted using the speaker button in the upper-right corner (see Figure 55).

6. COLOR LEGEND

For the SOH Overview and Station Statistics displays (Sections 5.2 and 5.3), the color legends in Figure 58 shows a station's capability-based SOH status (left) and whether the data are received (right). Alternatively, for channel/monitor pairs in the Station Statistics and Environment drilldown displays (Sections 5.3 and 5.4.5), the left color legend in
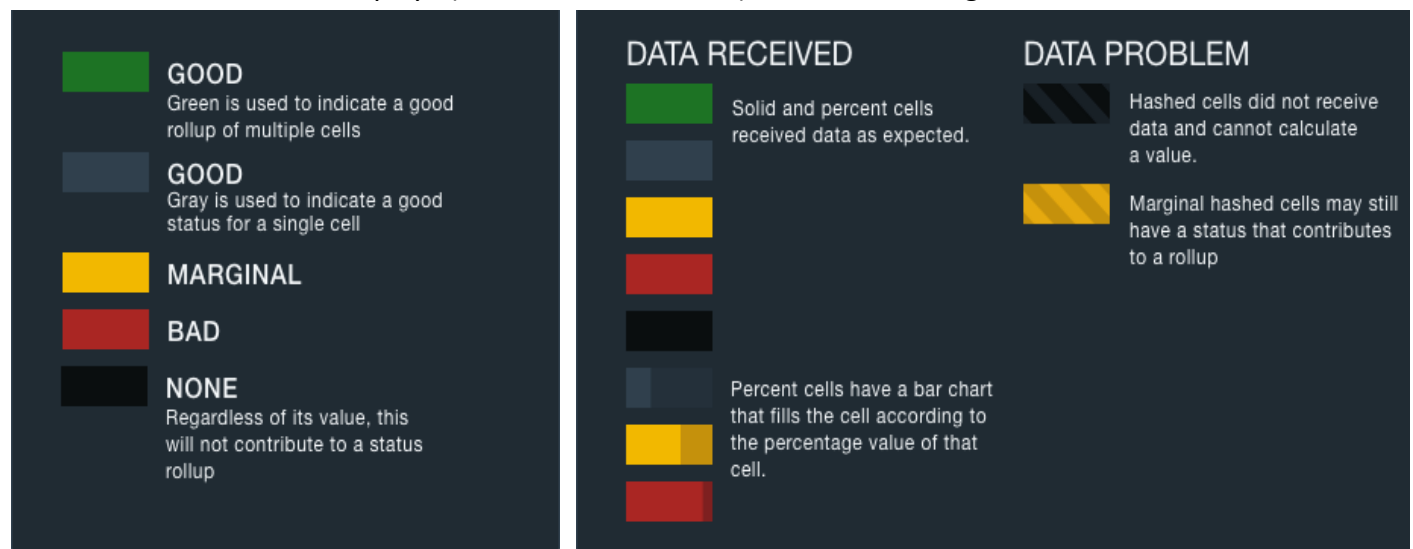
Figure 58 represents a channel/monitor pair's worst-of SOH status. Note that channels/monitors that did not receive data (hash-marked tiles in Figure 58) will have a value of Unknown.
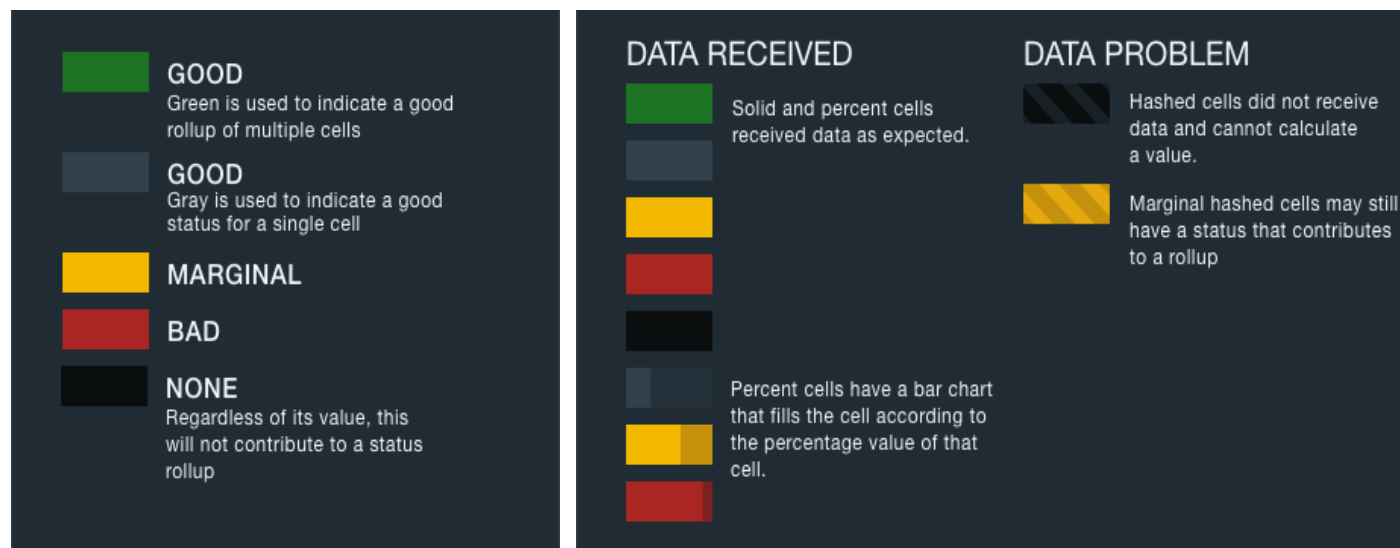
Figure 58. Capability-based SOH Status (Left) and Data Received (Right) Color Legends Shared Across Displays.

The color legend in Figure 59 shows the icons indicating a station's worst-of SOH status in the SOH Overview and Station Statistics displays (Sections 5.2 and 5.3).

Figure 59. Worst-of SOH status Color Legend in the SOH Overview and Station Statistics Displays.

A matrix illustrating all possible combinations of capability-based and worst-of SOH status symbols in the SOH Overview and Station Statistics displays is shown for station "ABCD" in Figure 60. Matrix rows correspond to capability-based SOH status and matrix columns correspond to the badge-icons representing worst-of SOH status. Note that there is no badge icon for a good worst-of SOH status.

Figure 60. Matrix of Capability-Based and Worst-of SOH Status Symbols.

The numbers to the left of the station name in the marginal and bad rows of the matrix are found in the Station Statistics display only (Section 5.3). These numbers are a count of the number of groups in which a station has a bad (top number) or marginal (bottom number) capability-based SOH status. There is no equivalent count for worst-of SOH status. See Section 5.3 for more details.

7. WORST-OF SOH STATUS AND CAPABILITY-BASED SOH STATUS ROLLUPS

This section details how the worst-of station SOH and capability-based SOH statuses are calculated.

7.1. Worst-of SOH Status Rollup

A station's worst-of SOH status notifies the user of the severity of the worst issue on that station. The worst-of SOH status of a station is inherited from the channel/monitor pair with the worst SOH status through a process called rollup. Rollup begins by determining the SOH status of each channel's monitors, see the right side of Figure 61. In the following examples, the available monitors are missing data, timeliness, lag, and environmental issues. Note that all environmental issues monitor types (e.g., Authentication Seal Broken, Clipped) are shown as a single box (labeled ENV_*) in Figure 61.
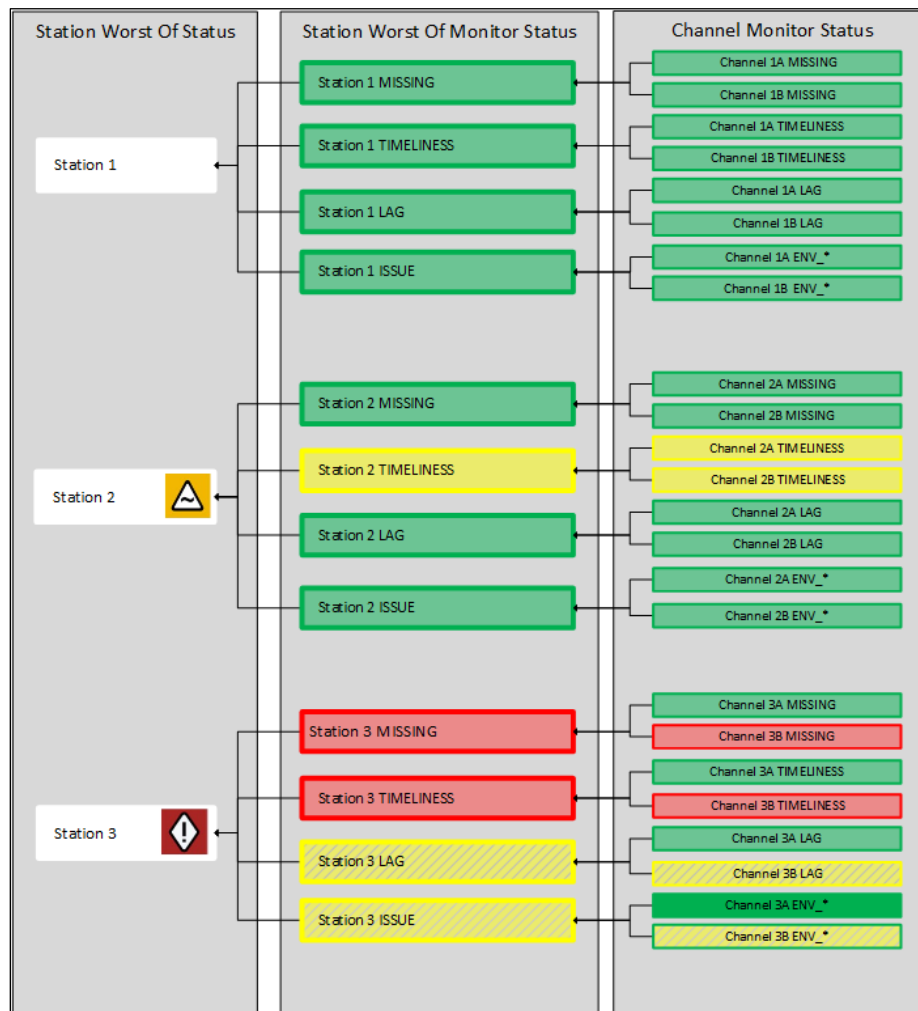
Figure 61. Flowchart Example of Worst-Of SOH Status Rollup.

After the SOH status of all a channel's monitors has been determined, these statuses are rolled up to the Station Worst-of Monitor Status level (middle column in Figure 61). At this level, the SOH status of a specific channel monitor type is compared across all channels and the worst status is inherited by the station monitor type, resulting in the Station Worst-of Monitor Status. These statuses are displayed in the Station Statistics display as the Channel Missing, Timeliness, Lag, and Issues columns (Figure 16).

The worst SOH status amongst the station monitor type statuses is inherited by the station as its Worst-of SOH status. Worst-of SOH status in the Overview and Station Statistics displays (Figure 10, Figure 16) is indicated by color and icon, with marginal = yellow triangle and bad = red diamond, see the left side of Figure 61. Note that a good worst-of SOH status does not have an icon.

For example, in Figure 61, Station 2 has two channels, 2A and 2B, each with the monitor types: missing data, timeliness, lag, and environment (right column of Figure 61). The missing data, lag, and environment monitors of Channels 2A and 2B have a good SOH status, while the timeliness monitors have a marginal SOH status. When these monitors are rolled up to the Station Worst-of Monitor status level (center column of Figure 61), the worst available status for the missing data, lag, and environmental issues monitors is good while the worst available status for timeliness is marginal. Thus, the resulting station monitor types, Station 2 Missing, Station 2 Lag, Station 2 Issue have an SOH status of good while Station 2 Timeliness has an SOH status of marginal. Finally, the four station monitor types are compared and the station inherits the worst station monitor SOH status as its worst-of SOH status. For Station 2, its overall worst-of SOH status is marginal because the worst station monitor SOH status is the Station 2 timeliness monitor with a status of marginal.

Monitors that are Unknown, i.e., had no data received and were configured to receive data, are classified as marginal worst-of SOH statuses and will contribute to the worst-of SOH Status rollup. An example of this type of status is shown for Station 3 at the bottom of Figure 61, with Channel 3B Lag and ENV_* having an Unknown status. This type of status typically arises if a channel or station are down and no longer transmitting data. If a station only has monitors with worst-of SOH statuses of good and marginal/Unknown, the station inherits a worst-of SOH status of marginal/Unknown; however, if a station's worst available monitors are a mix of marginal/Unknown and marginal with a numeric value, the station will inherit the worst-of SOH status of the monitor with the worst numeric value. In all cases, these inherited values can be seen in the Station Statistics display for a specific monitor under the Channel Missing, Timeliness, Lag, and Issues columns (Figure 16).

When calculating worst-of SOH status rollup, selected monitors and channels can be ignored by configuration (see Configuration documentation).

7.2. Capability-Based SOH Status Rollup

While the worst-of SOH status rollup notifies user's of issues with a station, the capability-based rollup helps prioritize which issues to troubleshoot first based on a station's importance to a configured capability. Capability-based rollups exist for stations and station groups. Station group capability-based rollup represents SOH statuses for a subset of stations in the group, while station capability-based rollup represents SOH statuses for a subset of channels in a station. In both cases, the subset of channels and monitors contribute as long as they meet a set of configured criteria.
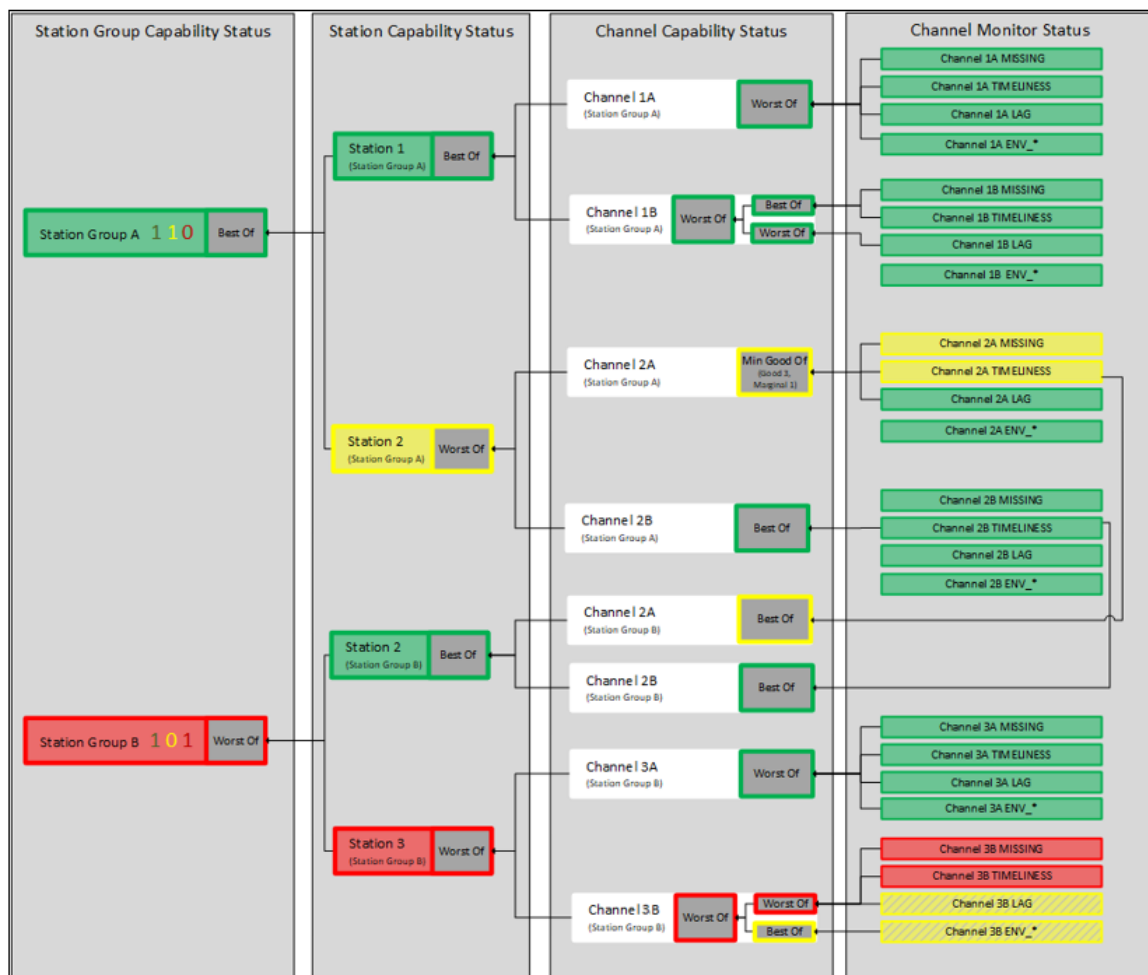
Figure 62. Flowchart Example of Capability-Based SOH Status Rollup.

Capability-based SOH status rollup calculation begins by calculating the SOH status of each channel's monitors, see the Channel Monitor Status column in Figure 62. The monitors include

missing data, timeliness, lag, and environmental issues. In Figure 62, all environment SOH monitor types are denoted as a single box and labeled as ENV_*.

Figure 62 depicts an arbitrary capability-based SOH status rollup, starting with monitors on the right and ending with station groups on the left. Arrows indicate which monitors, channels, or stations are input into a rollup operator (Worst-of, Best-of, or Min-Good-of). Capability-based SOH status is indicated by color in the SOH Overview and Station Statistics displays (Figure 10, Figure 16) with good = green, marginal = yellow, and bad = red.

A capability-based SOH status is only rolled-up if it meets criteria set by an applied rollup operator. There are three available rollup operators that can be applied to monitors, channels, or stations.

1) **Best-of** – Rolls up the best available monitor, channel, or station.

2) **Worst-of** – Rolls up the worst available monitor, channel, or station.

3) **Min-Good-of** – Rolls up the status of a monitor, channel, or station based on whether that SOH status meets or exceeds the marginal or good thresholds set by the user (see Configuration documentation).

A single operator can only have inputs of a single type, e.g., an input from a rollup operator and a monitor is not allowed. Additionally, rollup operators must obtain their capability-based SOH statuses using the hierarchy of stations, channels, and monitors. For instance, a station cannot get its capability-based SOH status directly from the monitors; it must get its status from the channels, which in turn got their SOH statuses from the monitors. The worst-of SOH status rollup described in Section 7.1 is a special case of the capability-based SOH status rollup described here, where only the Worst-Of operator is applied throughout the flowchart (Figure 61).

Figure 62 demonstrates how the capability-based SOH status rollup and the rollup operators work. In this figure, Channel 2A in Station Group A has three monitors, missing data, timeliness, and lag while Channel 2B in Station Group A only has timeliness, as indicated by the single arrow.

A Min-Good-Of operator was applied to all three monitors in Channel 2A. The Min-Good-Of operator is defined with two thresholds, Good: 3 and Marginal: 1. This can be seen in the Channel 2A box under the Channel Capability Status column. These thresholds indicate that the Min-Good-Of operator will return:

• A good SOH status when 3 or more monitors have a good SOH status,

• A marginal SOH status if just one monitor has a good SOH status, or

- A bad SOH status if zero monitors have a good SOH status.

In Figure 62, the lag monitor has a good SOH status, but the missing and timeliness monitors have a marginal SOH status; therefore, Min-Good-Of returns an SOH status of marginal for Channel 2A. The Best-Of operator is only applied to the timeliness monitor in Channel 2B; it returns a good SOH status for Channel 2B.

Sometimes a channel's capability-based SOH status can be further rolled up by another operator. This is the case for Channel 3B in Station Group B, which applies another Worst-of operator to the returned SOH statuses from Best-Of (marginal SOH status) and Worst-of (bad SOH status) operators, thus returning a bad Channel Capability status for Channel 3B. The operations described above are repeated until each channel has its own SOH status.

These channel SOH statuses are then input into rollup operators to determine the station's capability-based SOH status. A Worst-of operator is applied to Channels 2A (marginal) and 2B (good) in Station Group A, resulting in a marginal capability-based SOH status for Station 2 in Station Group A.

The capability-based SOH status rollup is repeated for each station until every station has a capability-based SOH status. Note that the same station, e.g., Station 2 in Figure 62, can have a different capability-based SOH status in different groups. In this example, Station 2 has a marginal status in Station Group A and a good status in Station Group B. The rollup operators are applied to all stations until a station group capability-based SOH status is obtained. In Figure 62, a Best-Of operator is applied to Station 1 (good SOH status) and Station 2 (marginal SOH status) to return a good capability-based SOH status for Station Group A.

Similar to channel SOH statuses, a capability-based SOH status of a station or station group can be further rolled up by another operator. Also, multiple operators can be applied to different channels within a station or to different stations within a station group.

As shown in Figure 62, capability-based SOH status rollups can be defined by changing the monitors, channels, or stations used, and also the number of inputs to a rollup operator, the rollup operators applied, and the Min-Good-Of thresholds used; however, further details on these capability-based SOH status rollup configurations are beyond the scope of this document. For more information, see the Configuration documentation.

8. GENERAL LIMITATIONS

If GMS stops receiving data for a configurable amount of time, the user will no longer be able to interact with the UI or any data that had already been loaded into the system. This state will be indicated by the Last Updated timestamp turning red (Figure 63, left). Depending on the display width, the user may need to click a colon symbol to view the Last Updated timestamp. This colon symbol will also turn red to indicate no data are being received (Figure 63, right).

Figure 63. Red Last Updated Time Stamp (Left) and Colon Symbol (Right).

In the Map display (Section 5.5), only the default imagery and terrain options (Natural Earth and WGS84, respectively) can be used.

In the historical trends displays, the number of available datapoints shown in the time-series plots is static such that when zooming in, no new datapoints are retrieved. Thus, highly decimated time-series may not be accurately shown when zoomed in to a certain degree.

In the SOH Environment display (Section 5.4.5), the monitor types Clock Differential in Microseconds, Last GPS Sync Time, and Station Power Voltage are always dark gray/hash-marked, i.e., they never receive data or contribute to the SOH status rollup.

Appendix A.   List of Environmental Issues

This is a list of available environmental issues in the SOH UI, specifically representative of CD1.1 Station Issues. This list can be configured to include other environmental issues (see Configuration documentation).

1) Authentication Seal Broken

2) Backup Power Unstable

3) Calibration Underway

4) Clipped

5) Clock Differential in Microseconds

6) Clock Differential Too Large

7) Dead Sensor Channel

8) Digitizer Analog Input Shorted

9) Digitizer Calibration Loop Back

10) Digitizing Equipment Open

11) Equipment Housing Open

12) Equipment Moved

13) Gps Receiver Off

14) Gps Receiver Unlocked

15) Last Gps Sync Time

16) Main Power Failure

17) Station Power Voltage

18) Vault Door Opened

19) Zeroed Data

Appendix B.   System Message Definitions

Message Type	Severity	Category	Subcategory	Message String	Message Purpose
Station needs attention	Critical	SOH	Station	Station <station> needs attention	Record that a station has been added to the Needs Attention bin on the SOH display.
Station worst-of SOH status changed	Info	SOH	Station	Station <station> worst-of SOH status changed from <previous_status> to <current_status>	Record changes in pure worst-of Station SOH rollup status for every station.
Station capability-based SOH status changed	Warning	SOH	Capability	Station <station> capability-based status for Station Group <group> changed from <previous_status> to <current_status>	Record changes in station SOH rollup status for every station used in every capability-based rollup.
Station Group capability-based SOH status changed	Warning	SOH	Capability	Station Group <group> capability status changed from <previous_status> to <current_status>	Record changes in station group capability-based rollup status for every station group.
Channel/Monitor Type status changed	Info	SOH	Station	Station <station> Channel <channel> <monitor_type> status changed from <previous_status> to <current_status>	Record changes in SOH Status for every channel SOH monitor
Channel/Monitor Type status change acknowledged	Info	SOH	User	Without comment: Station <station> Channel <channel> <monitor_type> status	Record channel SOH monitor status change acknowledgements

Message Type	Severity	Category	Subcategory	Message String	Message Purpose
				change acknowledged by user <username> With comment: Station <station> Channel <channel> <monitor_type> status change acknowledged by user <username> with comment '<comment>'	
Channel/Monitor Type quieted	Warning	SOH	User	Without comment: Station <station> Channel <channel> <monitor_type> quieted for <time interval> by user <username> With comment: Station <station> Channel <channel> <monitor_type> quieted for <time interval> by user <username> with comment '<comment>'	Record when the System Controller manually changes or cancels the quieting period for any channel SOH monitor.
Channel/Monitor Type quiet period canceled	Info	SOH	User	Station <station> Channel <channel> <monitor_type> quiet period canceled by user <username>	Record when the quieting period is canceled for any channel SOH channel/monitor pair

Message Type	Severity	Category	Subcategory	Message String	Message Purpose
Channel/Monitor Type quiet period expired	Info	SOH	Station	Station <station> Channel <channel> <monitor_type> quiet period expired	Record when the quieting period expires for any channel/monitor pair

Appendix C.   Hot Keys

The following tables list hot keys available for each display. When available, alternate hot keys are also listed.

Appendix C.1.   Station Overview/Station Statistics Display

Operation	Hot Key	Alternate	Notes
Open Menu to Acknowledge Station	Right Click on Station Label		Use Ctrl on Windows, Cmd (i.e., Command) on Mac
Modify (Add or Remove) Current Station Selection	Ctrl/Cmd + Click on Station Label		Use Ctrl on Windows, Cmd (i.e., Command) on Mac
Select Range of Stations	Shift + Click on Station Label		

Appendix C.2.   SOH Lag/Missing/Timeliness Drilldown Displays

Operation	Hot Key	Alternate	Notes
Generate New Brush Window	Click + Mouse Drag to Right		Brush window appears as a white rectangle on the secondary display (see Figure 27).
Modify Brush Window	Click + Drag Rectangle Edge		Double-arrow should be visible while dragging
Open Menu to Quiet Channel	Right-click Bar or Channel Name		

Appendix C.3.   SOH Environment Drilldown Display

Operation	Hot Key	Alternate	Notes
Open Menu to Quiet Channel Environmental Issue	Right-click on Desired Cell		Cell will correspond to a specific combination of channel + environmental issue

Appendix C.4.   SOH Lag/Missing/Timeliness/Environment Trends Drilldown Displays

Operation	Hot Key	Alternate	Notes
Zoom in	(Ctrl/Cmd + Click) Mouse Drag	(Ctrl/Cmd + Scroll Wheel)	Use Ctrl on Windows, Cmd (i.e., Command) on Mac
Zoom Out	Double Click	(Ctrl/Cmd + Scroll Wheel)	Use Ctrl on Windows, Cmd (i.e., Command) on Mac
Print Time to Screen	Click + Hold		