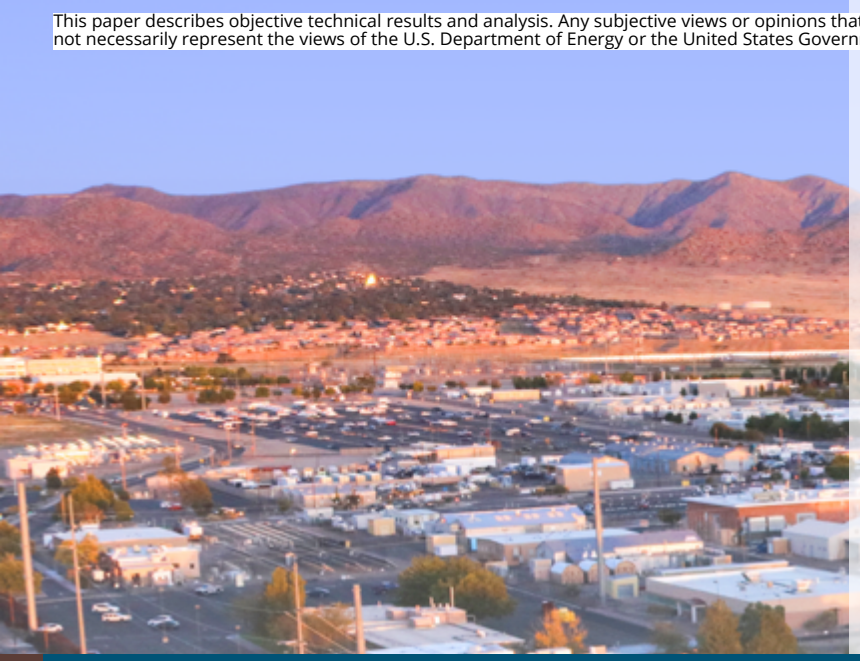
SAND2023-07767C



GMS

Geophysical Monitoring System

GMS Overview

Presented by: Andrea Conley, GMS SME Team Lead

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY NNSA

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for providing slides used in

Fundamental Nuclear Monitoring Questions

Detection: Did an event occur?

- Must detect the event or there is no information to report

Location: Where did it occur?

- Location tells us who the likely responsible party was

Magnitude/Yield: How big was it?

- Size is relevant for specific treaty language, and also because it tells us something about the type of device

Identification (Discrimination): What was it?

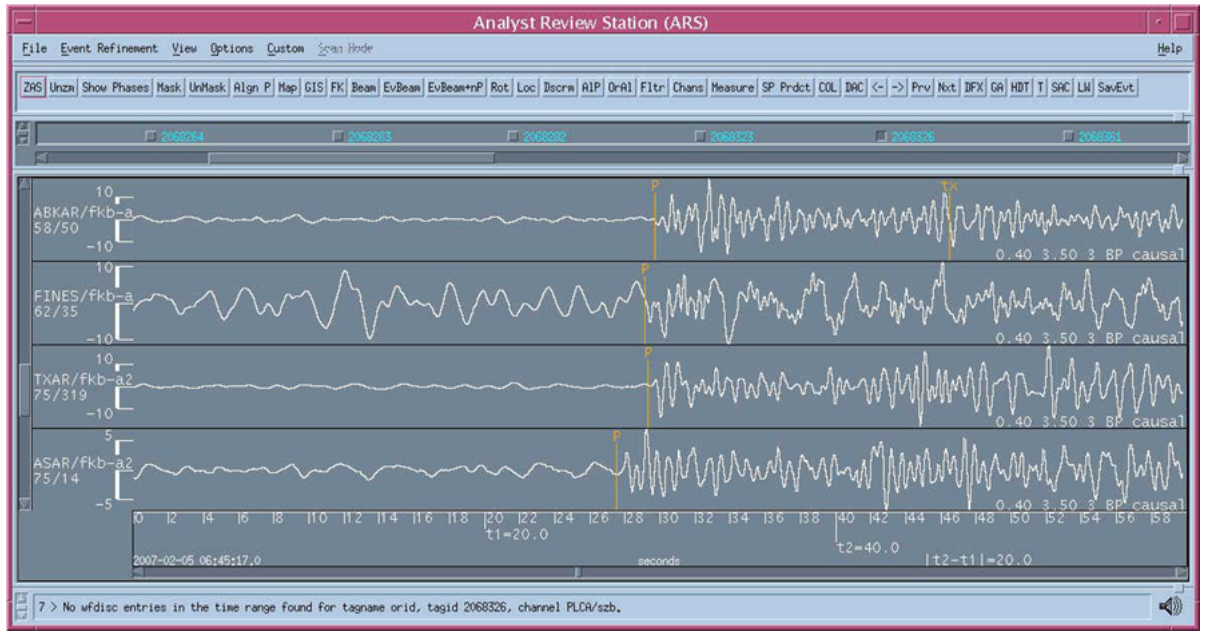
- Obviously we only want to report nuclear explosions, but unfortunately we generally have to go through the previous steps before we can figure out what type of event it was (e.g. earthquake or explosion)

History and Purpose of GMS

- To answer the fundamental nuclear monitoring questions on location, discrimination, etc., the Analyst Review Station (ARS) was made in the 1990s and has been in use ever since at the U.S. National Data Center (USNDC) and the International Data Centre (IDC).

- The systems have become difficult to maintain and enhance, and thus require modernization.

- SNL is developing the Geophysical Monitoring System (GMS) to modernize and replace ARS.
  - GMS is an interactive analysis tool to be used by seismic, hydroacoustic, and infrasound analysts to detect, locate, estimate yield/magnitude, and identify events of interest.
  - GMS will provide a more modern, efficient, and extensible system than ARS.
  - The effort includes development of data services that “bridge” the data from the legacy database system to a GMS Common Object Interface (COI) format and make this data available through web services to GMS applications and external users.



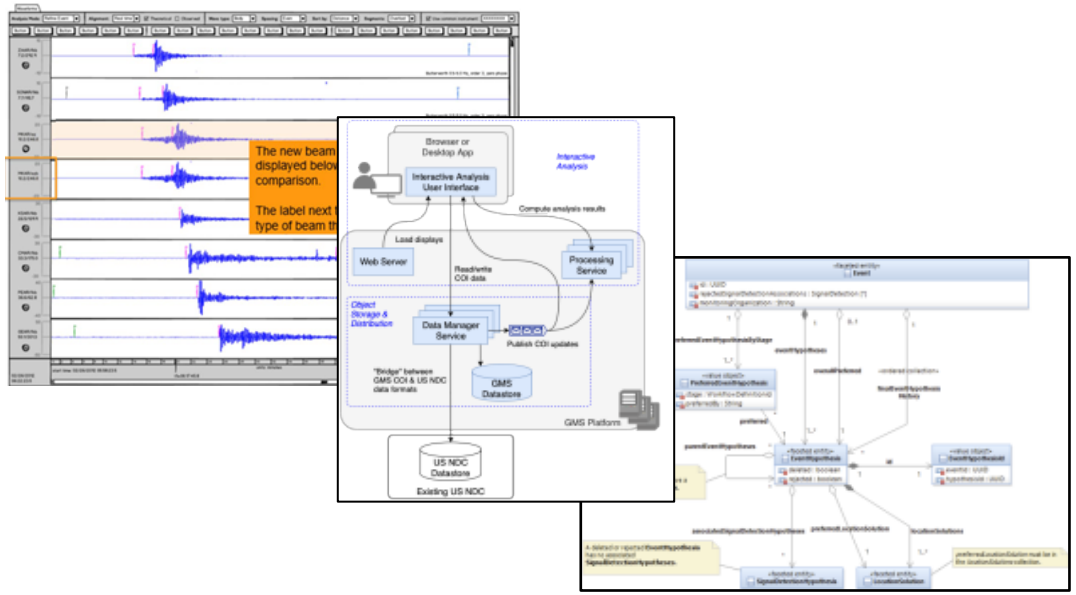
- SNL is developing GMS for the USNDC modernization effort and is also providing two open source software releases per year to the IDC
  - Open source releases have been provided since 2018 on

Methodology

Product Design and Architecture

GMS is a large software development project with several development teams, plus architecture, geoscience, platform, and test teams.

Product Management defines and prioritizes a capability roadmap, and along with user experience and architecture develops product guidance for developers in the form of descriptions, storyboards, and architecture designs.

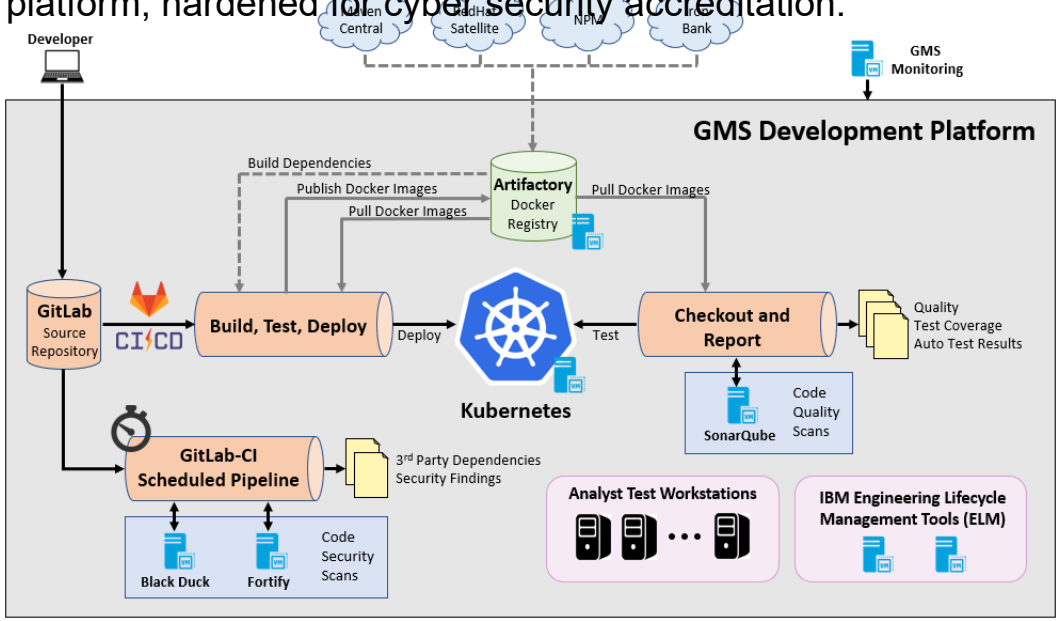


Development and Deployment

GMS uses agile development practices, working in two week iterations. GMS developers manage code and workflow in GitLab.

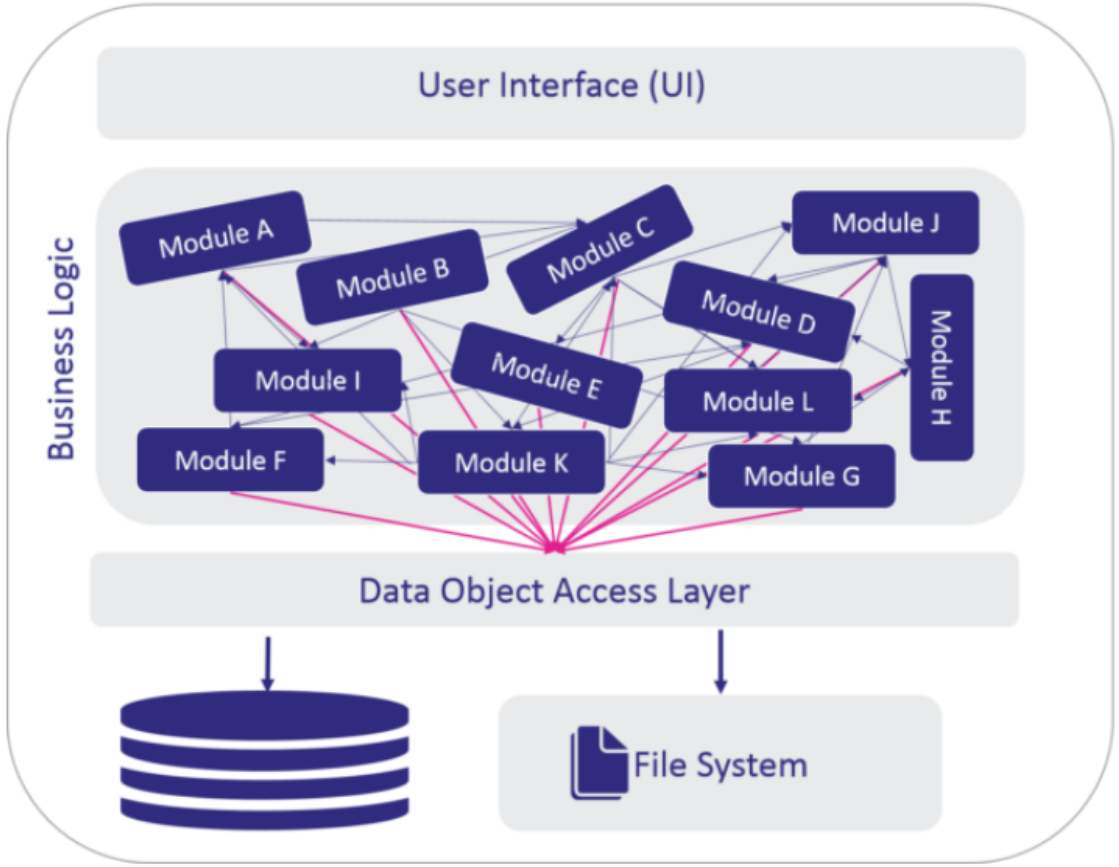
We use GitLab Continuous Integration / Continuous Deployment (CI/CD) to automate software build, test, and deployment pipelines.

GME is deployed using a cloud-ready Kubernetes containerized platform, hardened for cyber security accreditation.



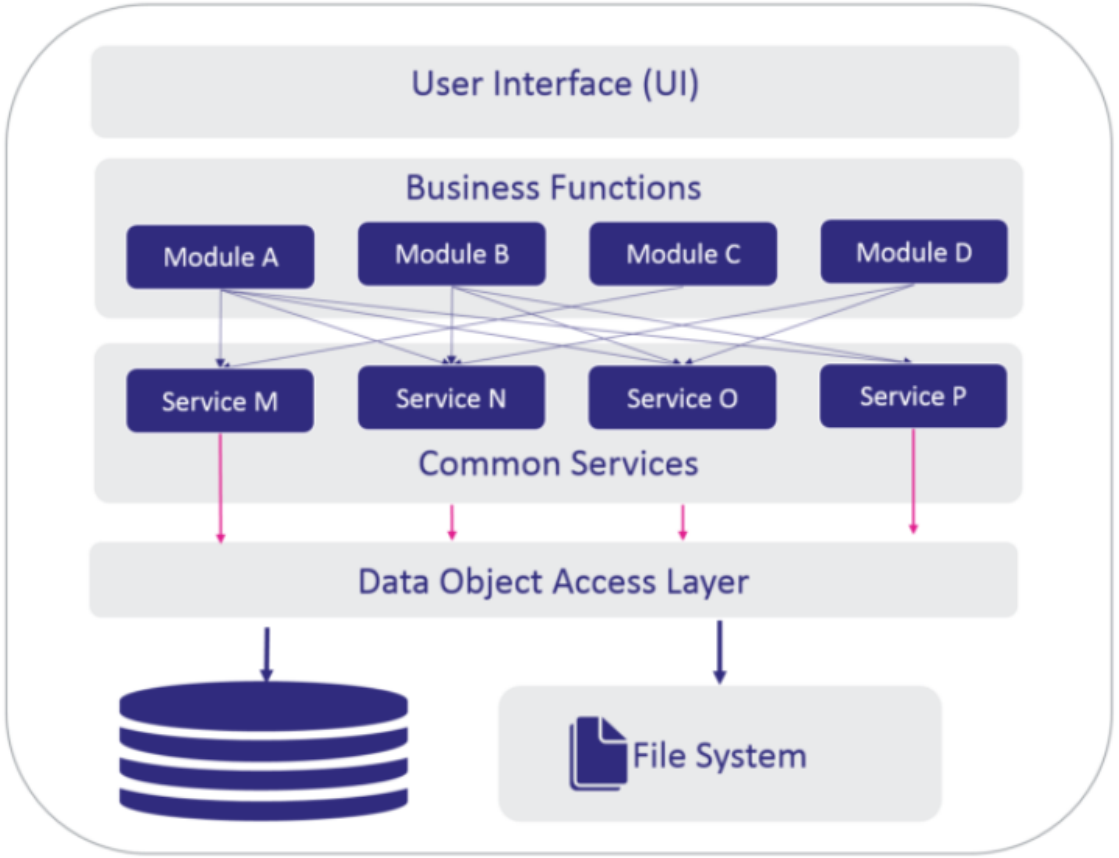
US NDC Modernization (The Software Architecture)

Monolithic Architecture



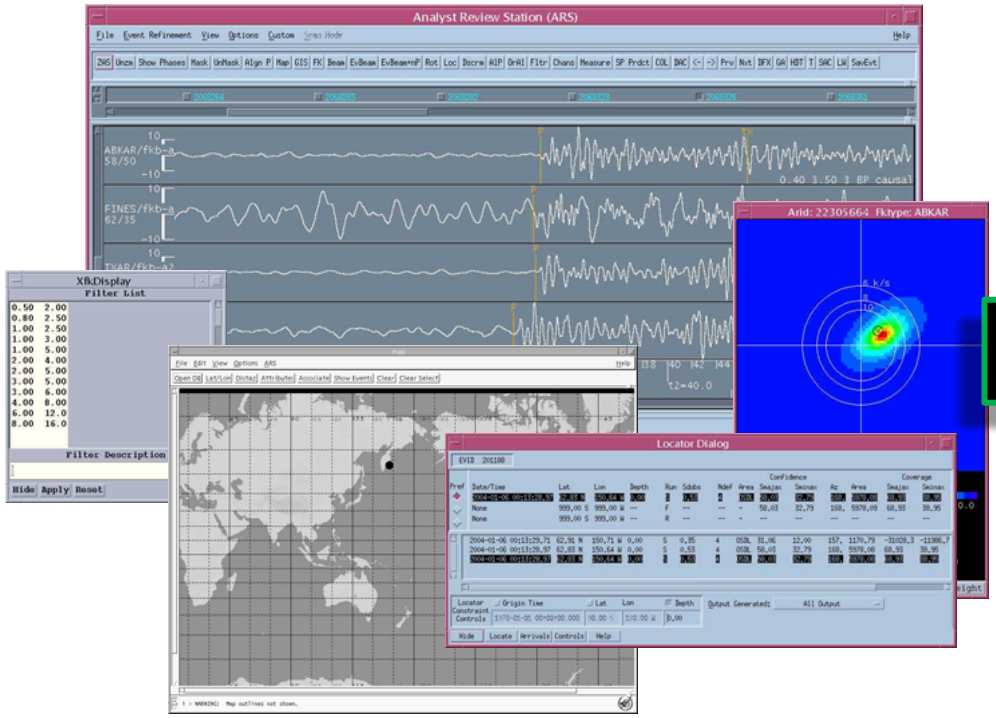
Legacy

Service-Oriented Architecture



GMS

US NDC Modernization (The User Interface)



Legacy System

WEBASSEMBLY

TypeScript

GraphQL

React

CESIUM

ELECTRON

GMS Applications: Interactive Analysis (IAN)

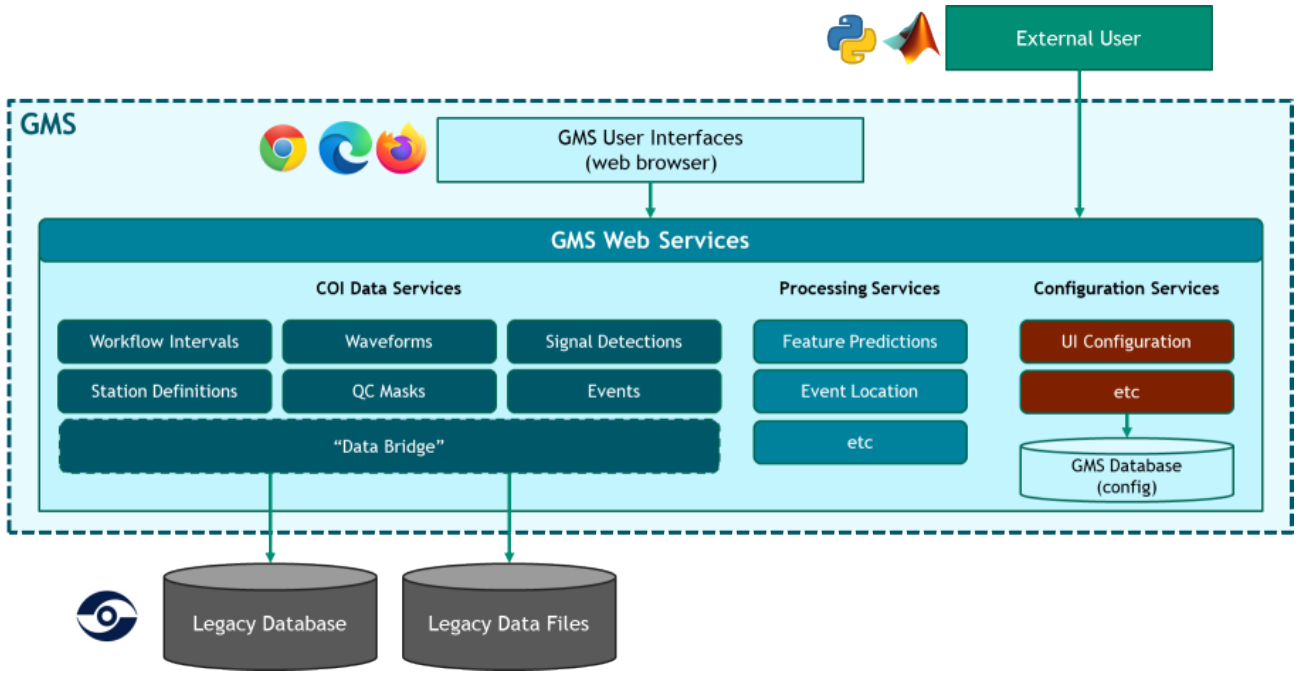
IAN Overview

- IAN provides several interactive analysis capabilities. The current open-source release includes the ability to access, modify, and display:
  - Station metadata
  - Waveforms
  - Quality Control (QC) masks
  - Signal detections
  - Events

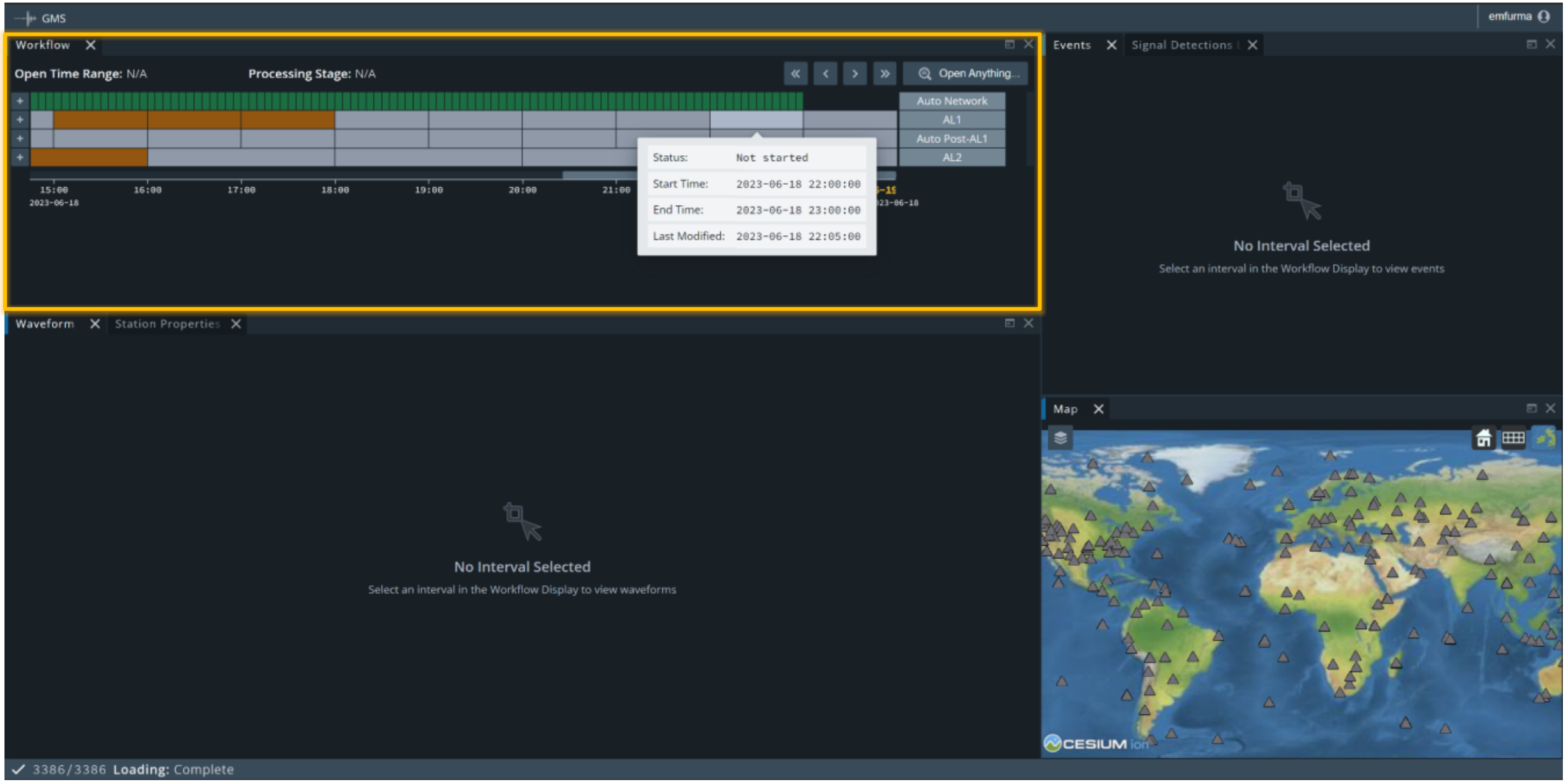
- Seismic, hydroacoustic, and infrasound (SHI) data can be accessed in IAN.

- IAN uses modern web technology (e.g., Cesium, WebAssembly (WASM), etc.) to access the stored data (from the legacy database in this case) and provide the data for display and interaction.

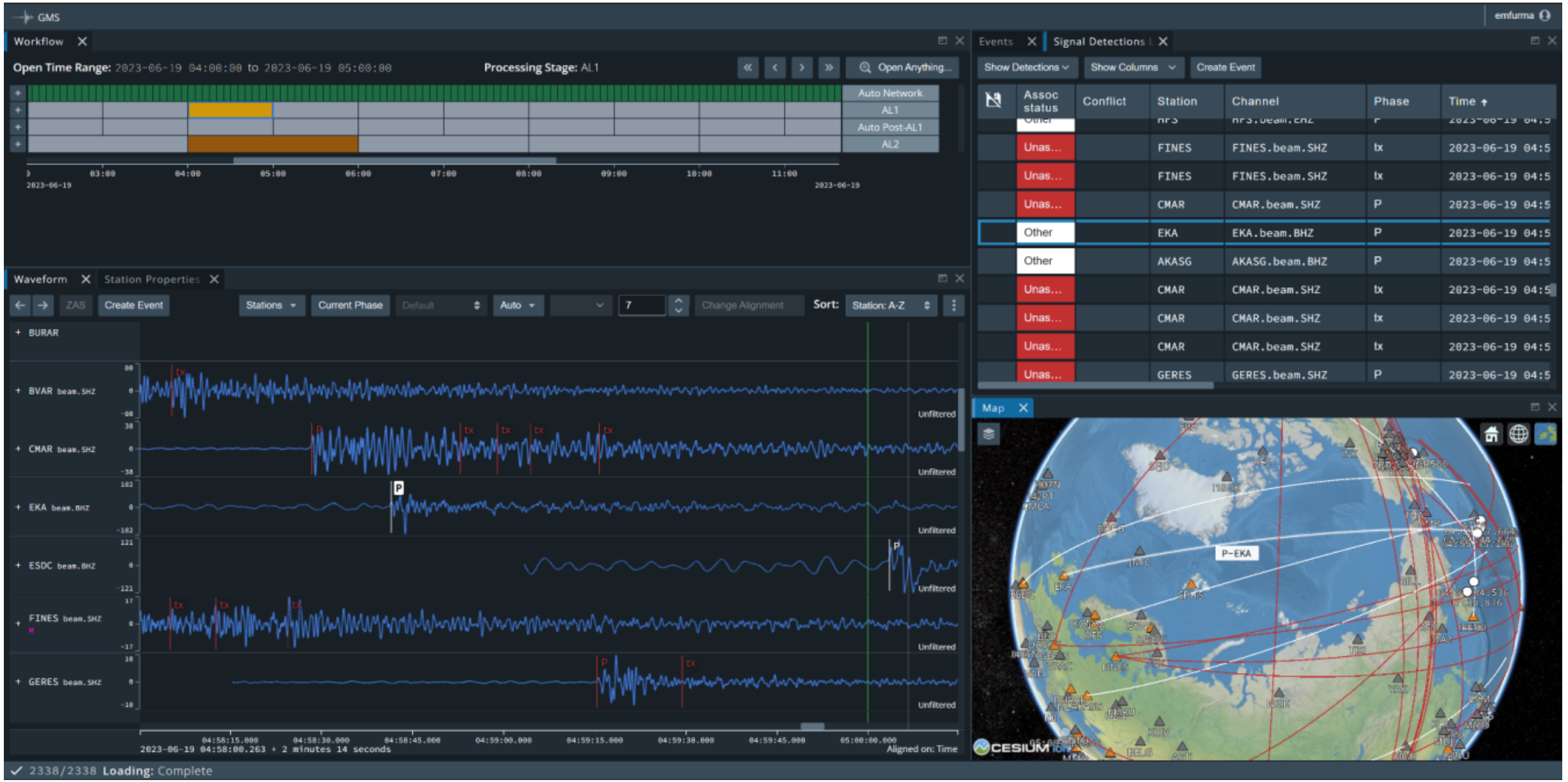
- Data and user operations are fully synchronized across all displays, with consistent user experience design. Displays



Getting Started with Workflow



IAN With Interval Opened

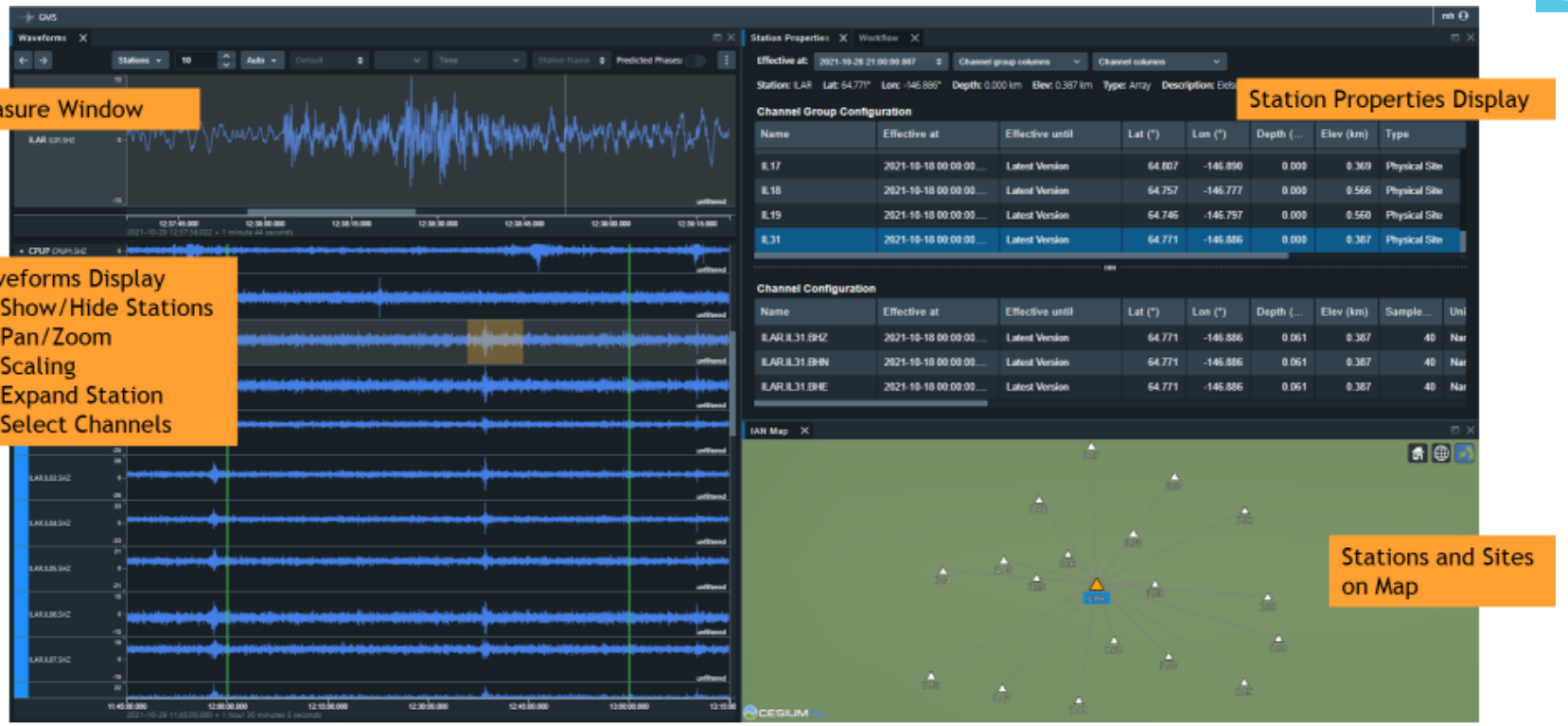


Station and Waveform Analysis Features in Opened Interval

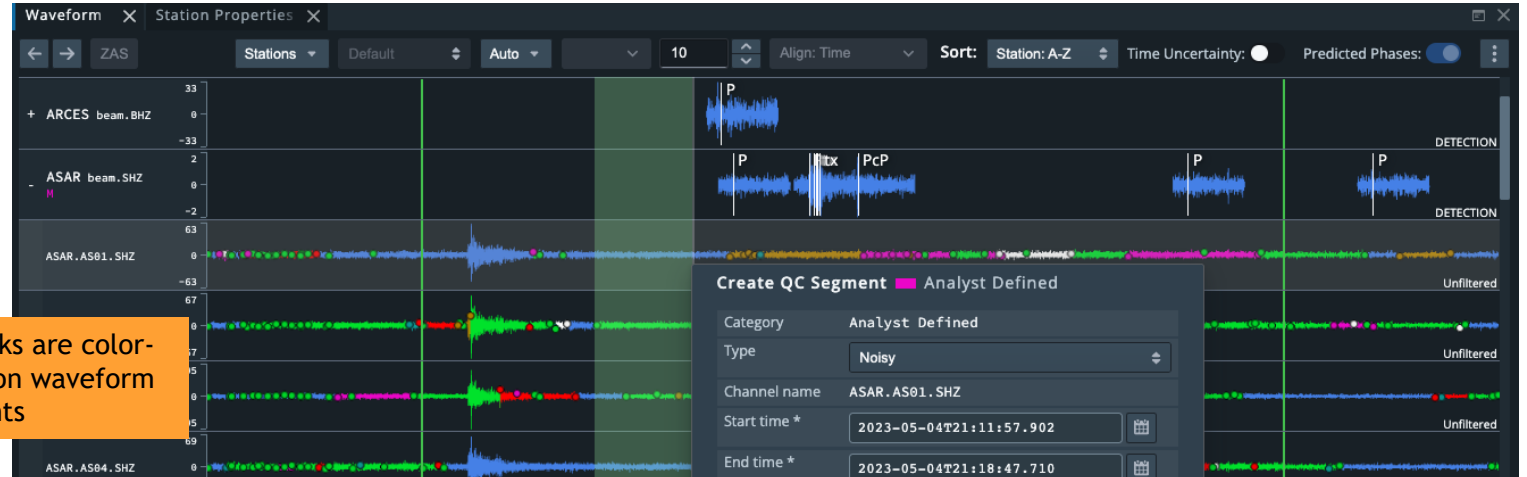
Waveform Viewing
- Beams and Raw Waveforms
- Zoom and pan
- Amplitude scaling
- Interactive QC masks
- Measure Window (zoomed waveform segment)

Station Viewing
- Map – station and site icons
- Station Properties – text attributes for stations, site, channels
- Waveform Display – show and hide stations

Waveform Analysis (next release)
- Edit QC masks
- Waveform filtering



Station information and Waveforms bridged from the legacy database



QC Masks are color-coded on waveform segments

Signal Detection Analysis Features

Signal Detection Viewing
- Color-coded based on association status
- Signal Detection List – text attributes
- Waveform Display – phase marker, arrival time, uncertainty
- Map – great circle path

Signal Detection Editing (next release)
- Create and reject
- Change arrival time (drag & drop)
- Change time uncertainty
- Change phase label
- View signal detection association conflicts

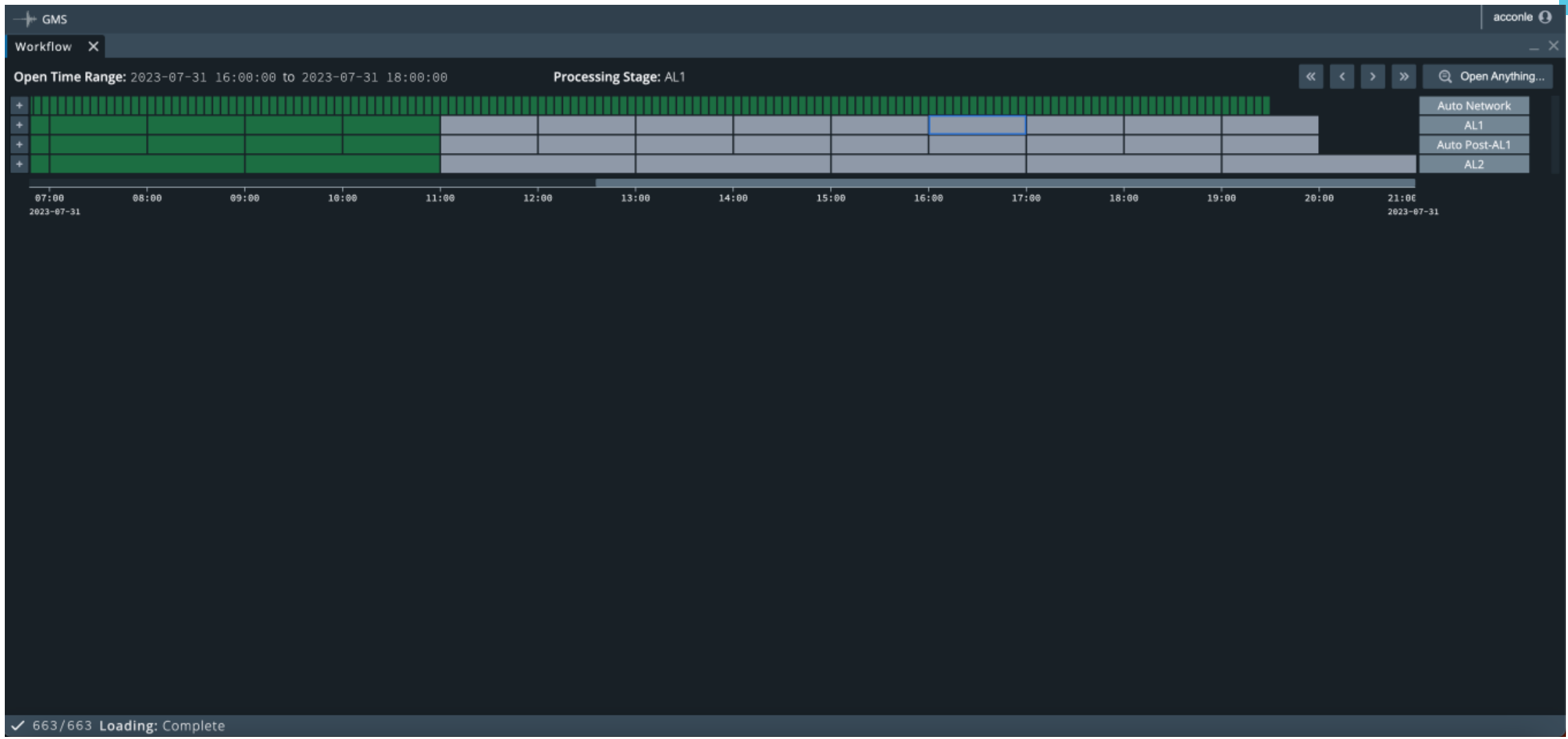
Event Analysis Features

Event Viewing
- Color-coded based on review status
- Event List – text attributes, workflow progress
- Map – location and uncertainty ellipse
- Waveform Display – zoom/align/sort for open event
- Waveform Display – travel time predictions

Event Editing (next release)
- Create, duplicate, reject
- Associate or disassociate Signal Detections
- View event association conflicts

IAN Displays

Workflow Display



- When using the IAN display, both the GMS system and human analysts work on the available waveform data in different processing stages, where each processing stage consists of a different set of processing sequences or activities applied to the data. These stages are listed in the rightmost column of the Workflow display.

Waveform Display

- The Waveform display supports the querying, viewing, and analysis of waveform beams, the raw waveforms they comprise, and their associated signal detections, as recorded at stations in a configured default station group during a specified time interval.

Event Display

GMS

acconle

Events | Signal Detections

Complete 000 Remaining 044 Conflicts 000 Deleted 000 Rejected 000

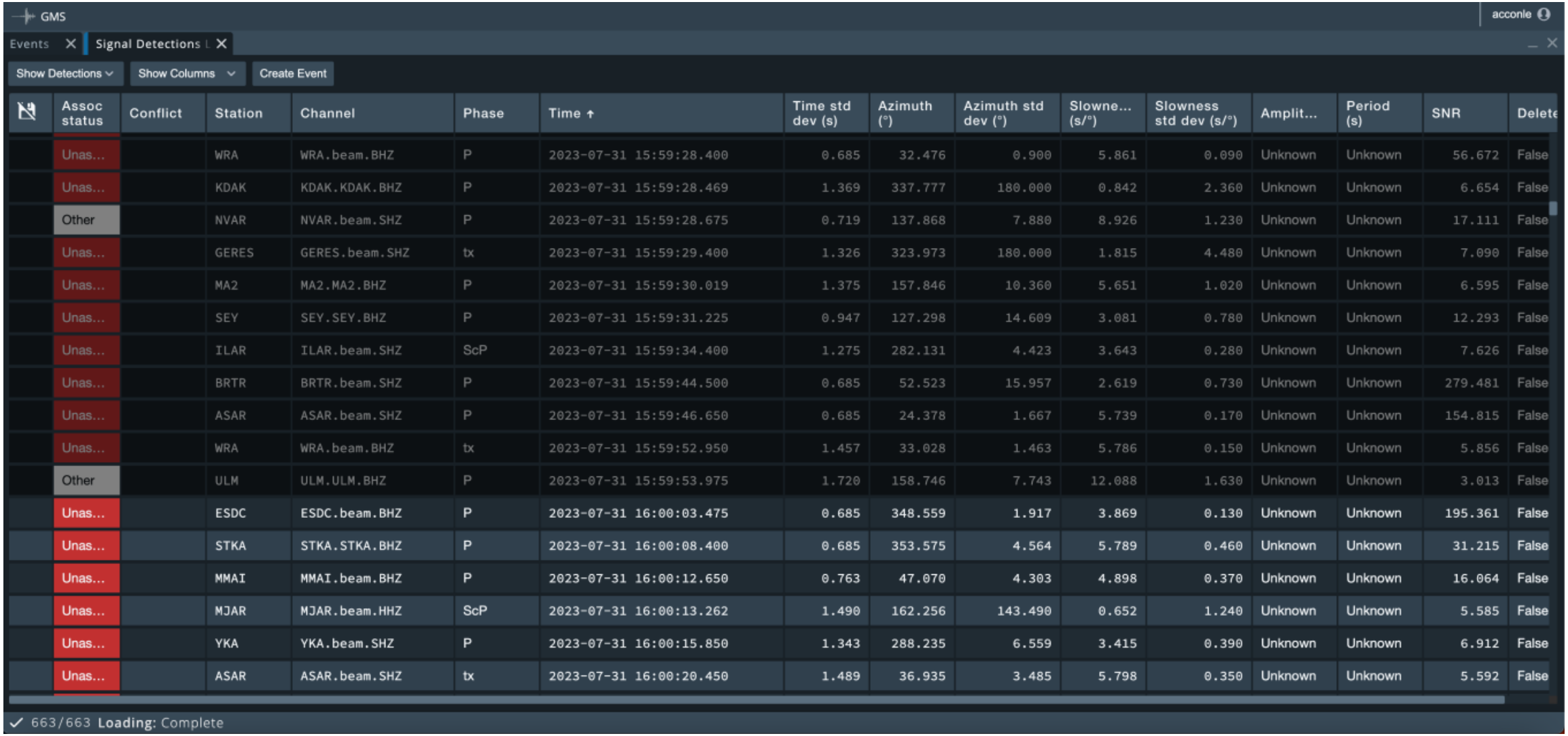
Show Events | Show Columns | Create Event | Mark Selected Complete

Conflict	Time ↑	Lat (°)	Lon (°)	Depth (km)	mb	ms	ml	# Associated	# Defining	Sdobs	Coverage semi-major	Coverage semi-minor	Confidence semi-major	Confid semi-r
	2023-07-31 15:47:06.635 ± 0.374s	51.383	-178.225	0.000	5.4			132	0	0.687	13.00	10.12	11.31	
	2023-07-31 15:52:58.935	14.494	-93.021	45.583	4.3			19	12	2.120	Unknown	Unknown	41.98	
	2023-07-31 15:55:06.998	-18.505	-172.302	0.000	4.6			32	16	3.323	Unknown	Unknown	42.37	
	2023-07-31 15:55:35.186	52.432	-179.441	0.000	3.8			2	2	0.023	Unknown	Unknown	1,259.35	
	2023-07-31 15:59:57.664	50.561	-175.871	650.148	3.0			10	6	2.604	Unknown	Unknown	65.32	
	2023-07-31 16:03:41.770	51.467	-178.145	182.761	3.5			12	0	75.371	Unknown	Unknown	37.99	
	2023-07-31 16:05:49.102	-11.640	-66.209	0.000	3.6			1	1	1.673	Unknown	Unknown	86.96	
	2023-07-31 16:07:29.406	-55.405	62.749	0.000	3.9			4	2	0.944	Unknown	Unknown	58.83	
	2023-07-31 16:08:33.656	33.928	31.207	0.000	3.9			8	0	0.750	Unknown	Unknown	84.38	
	2023-07-31 16:11:49.822	-21.631	22.050	0.000				0	0	32.861	Unknown	Unknown	352.10	
	2023-07-31 16:13:25.680	15.465	95.931	0.000	3.8			2	2	0.094	Unknown	Unknown	228.04	
	2023-07-31 16:19:09.369	34.583	46.384	0.000	4.0			24	0	2.523	Unknown	Unknown	27.02	
	2023-07-31 16:22:52.769	-3.302	151.003	0.000	3.3			3	3	0.897	Unknown	Unknown	138.15	
	2023-07-31 16:24:02.071	13.044	137.353	0.000	3.9			3	3	0.195	Unknown	Unknown	103.34	
	2023-07-31 16:25:38.827 ± 0.271s	-8.104	-71.590	585.393 ± 2.465	5.6			240	0	1.383	7.98	6.07	6.94	
	2023-07-31 16:26:27.314	-3.173	140.778	291.655	3.6			10	0	2.166	Unknown	Unknown	44.00	
	2023-07-31 16:26:31.897	-9.055	-71.501	0.000	5.8			2	2	2.186	Unknown	Unknown	114.13	

663/663 **Loading:** Complete

- The Events display allows users to 1) view detailed event information for bridged events within the time range selected in the Workflow display, 2) open and close events, and 3) modify events (i.e., reject, delete, etc.).

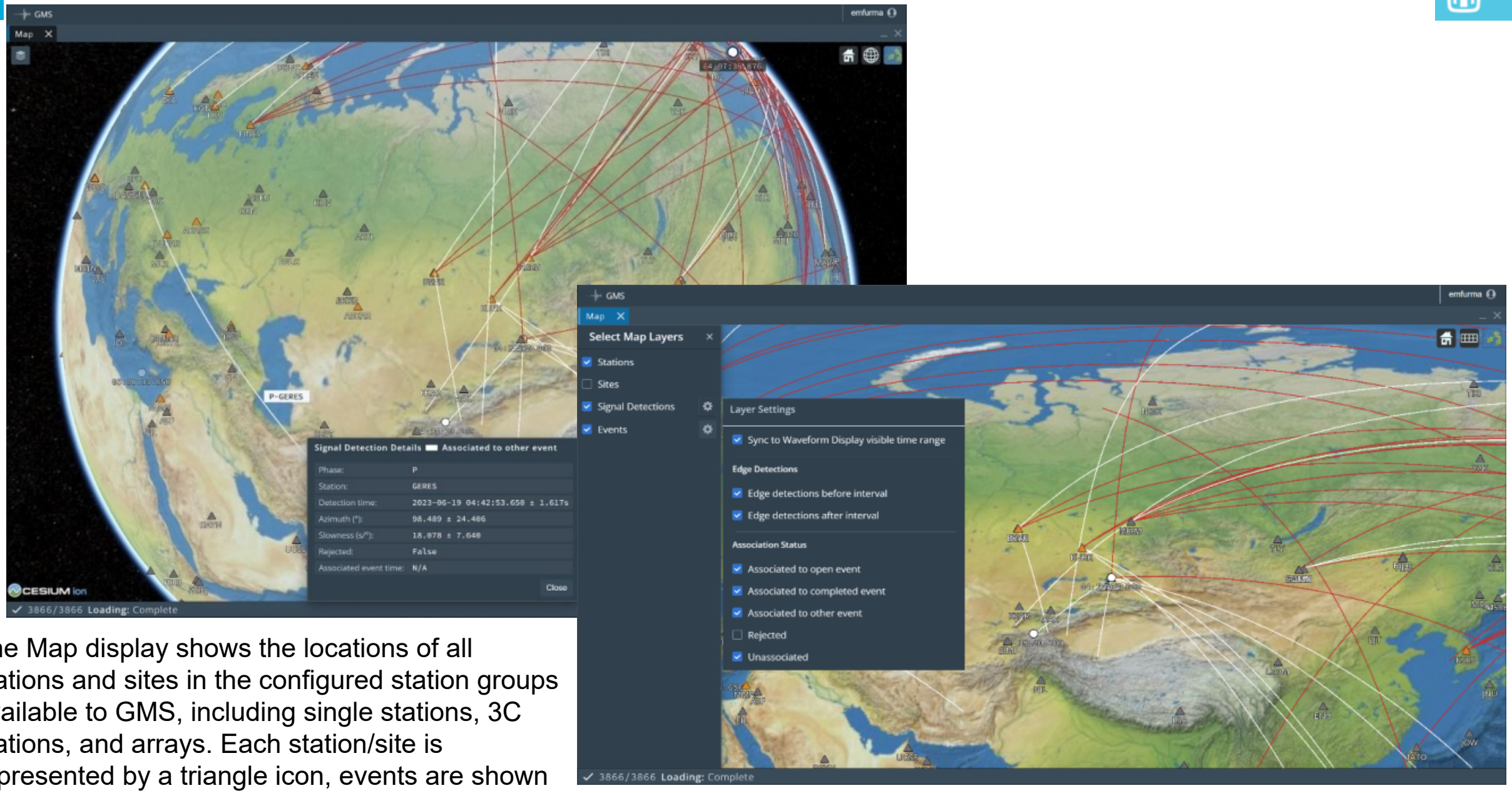
Signal Detections List Display



Assoc status	Conflict	Station	Channel	Phase	Time ↑	Time std dev (s)	Azimuth (°)	Azimuth std dev (°)	Slowne... (s/°)	Slowness std dev (s/°)	Amplit...	Period (s)	SNR	Delete
Unas...		WRA	WRA.beam.BHZ	P	2023-07-31 15:59:28.400	0.685	32.476	0.900	5.861	0.090	Unknown	Unknown	56.672	False
Unas...		KDAK	KDAK.KDAK.BHZ	P	2023-07-31 15:59:28.469	1.369	337.777	180.000	0.842	2.360	Unknown	Unknown	6.654	False
Other		NVAR	NVAR.beam.SHZ	P	2023-07-31 15:59:28.675	0.719	137.868	7.880	8.926	1.230	Unknown	Unknown	17.111	False
Unas...		GERES	GERES.beam.SHZ	tx	2023-07-31 15:59:29.400	1.326	323.973	180.000	1.815	4.480	Unknown	Unknown	7.090	False
Unas...		MA2	MA2.MA2.BHZ	P	2023-07-31 15:59:30.019	1.375	157.846	10.360	5.651	1.020	Unknown	Unknown	6.595	False
Unas...		SEY	SEY.SEY.BHZ	P	2023-07-31 15:59:31.225	0.947	127.298	14.609	3.081	0.780	Unknown	Unknown	12.293	False
Unas...		ILAR	ILAR.beam.SHZ	ScP	2023-07-31 15:59:34.400	1.275	282.131	4.423	3.643	0.280	Unknown	Unknown	7.626	False
Unas...		BRTR	BRTR.beam.SHZ	P	2023-07-31 15:59:44.500	0.685	52.523	15.957	2.619	0.730	Unknown	Unknown	279.481	False
Unas...		ASAR	ASAR.beam.SHZ	P	2023-07-31 15:59:46.650	0.685	24.378	1.667	5.739	0.170	Unknown	Unknown	154.815	False
Unas...		WRA	WRA.beam.BHZ	tx	2023-07-31 15:59:52.950	1.457	33.028	1.463	5.786	0.150	Unknown	Unknown	5.856	False
Other		ULM	ULM.ULM.BHZ	P	2023-07-31 15:59:53.975	1.720	158.746	7.743	12.088	1.630	Unknown	Unknown	3.013	False
Unas...		ESDC	ESDC.beam.BHZ	P	2023-07-31 16:00:03.475	0.685	348.559	1.917	3.869	0.130	Unknown	Unknown	195.361	False
Unas...		STKA	STKA.STKA.BHZ	P	2023-07-31 16:00:08.400	0.685	353.575	4.564	5.789	0.460	Unknown	Unknown	31.215	False
Unas...		MMAI	MMAI.beam.BHZ	P	2023-07-31 16:00:12.650	0.763	47.070	4.303	4.898	0.370	Unknown	Unknown	16.064	False
Unas...		MJAR	MJAR.beam.HHZ	ScP	2023-07-31 16:00:13.262	1.490	162.256	143.490	0.652	1.240	Unknown	Unknown	5.585	False
Unas...		YKA	YKA.beam.SHZ	P	2023-07-31 16:00:15.850	1.343	288.235	6.559	3.415	0.390	Unknown	Unknown	6.912	False
Unas...		ASAR	ASAR.beam.SHZ	tx	2023-07-31 16:00:20.450	1.489	36.935	3.485	5.798	0.350	Unknown	Unknown	5.592	False

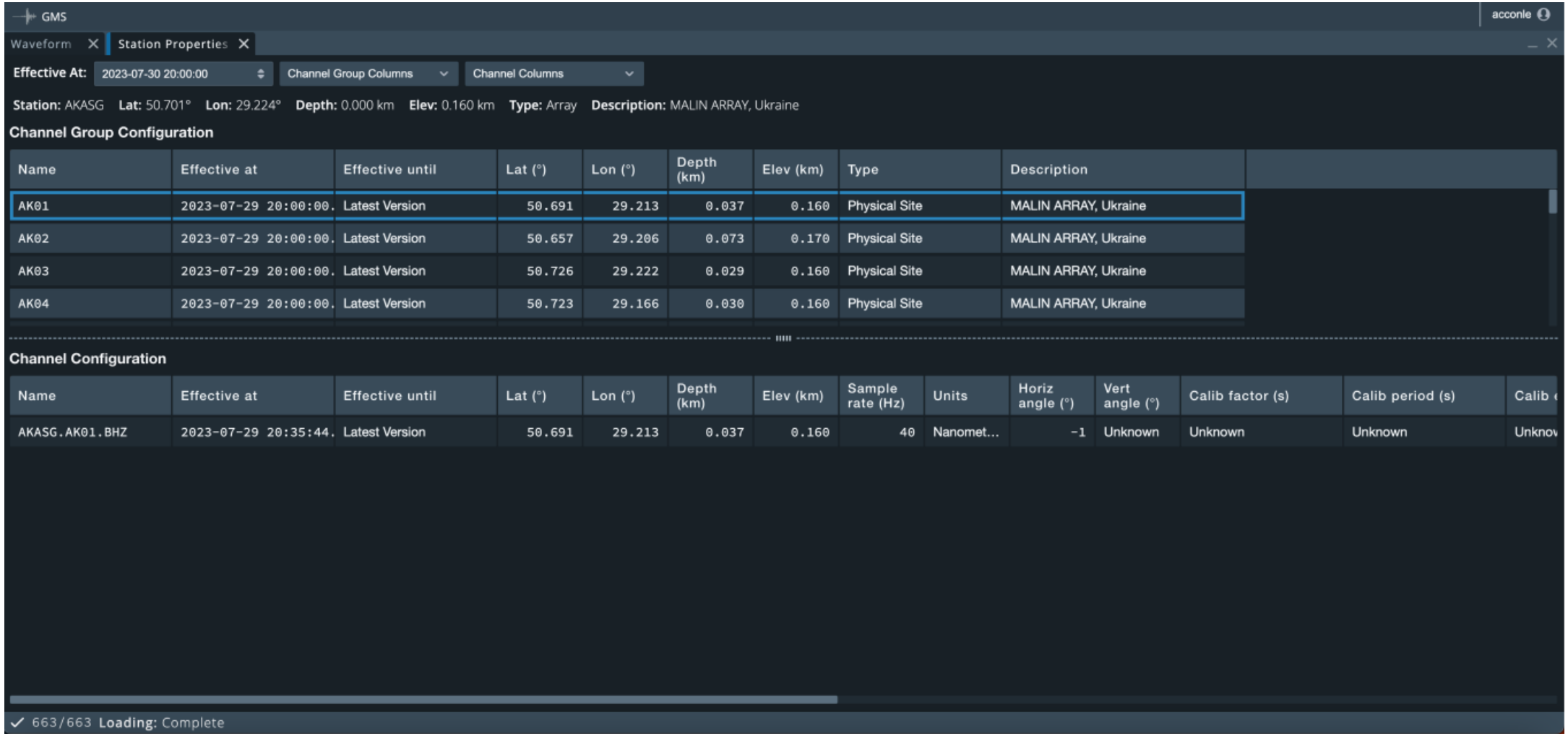
- The Signal Detections List display shows a tabular view of bridged signal detections (SDs), their corresponding metadata, and their association status. It also allows the user to modify SDs (i.e., reject, delete, etc.)

Map Display



- The Map display shows the locations of all stations and sites in the configured station groups available to GMS, including single stations, 3C stations, and arrays. Each station/site is represented by a triangle icon, events are shown by circular icons, and SDs are shown as great

Station Properties Display

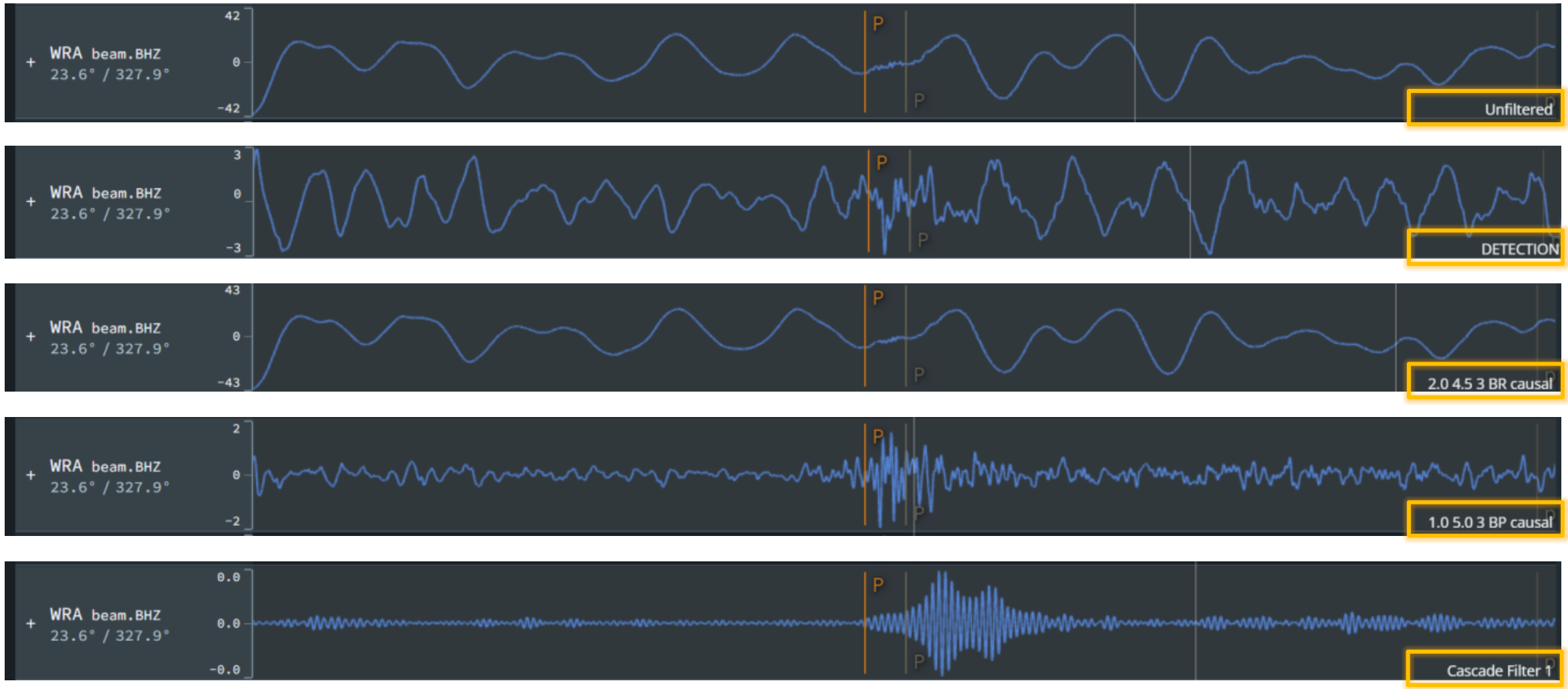


- The Station Properties display allows users to view detailed metadata information about a selected station (channel group and channel configuration) in either the Map or Waveform Displays.

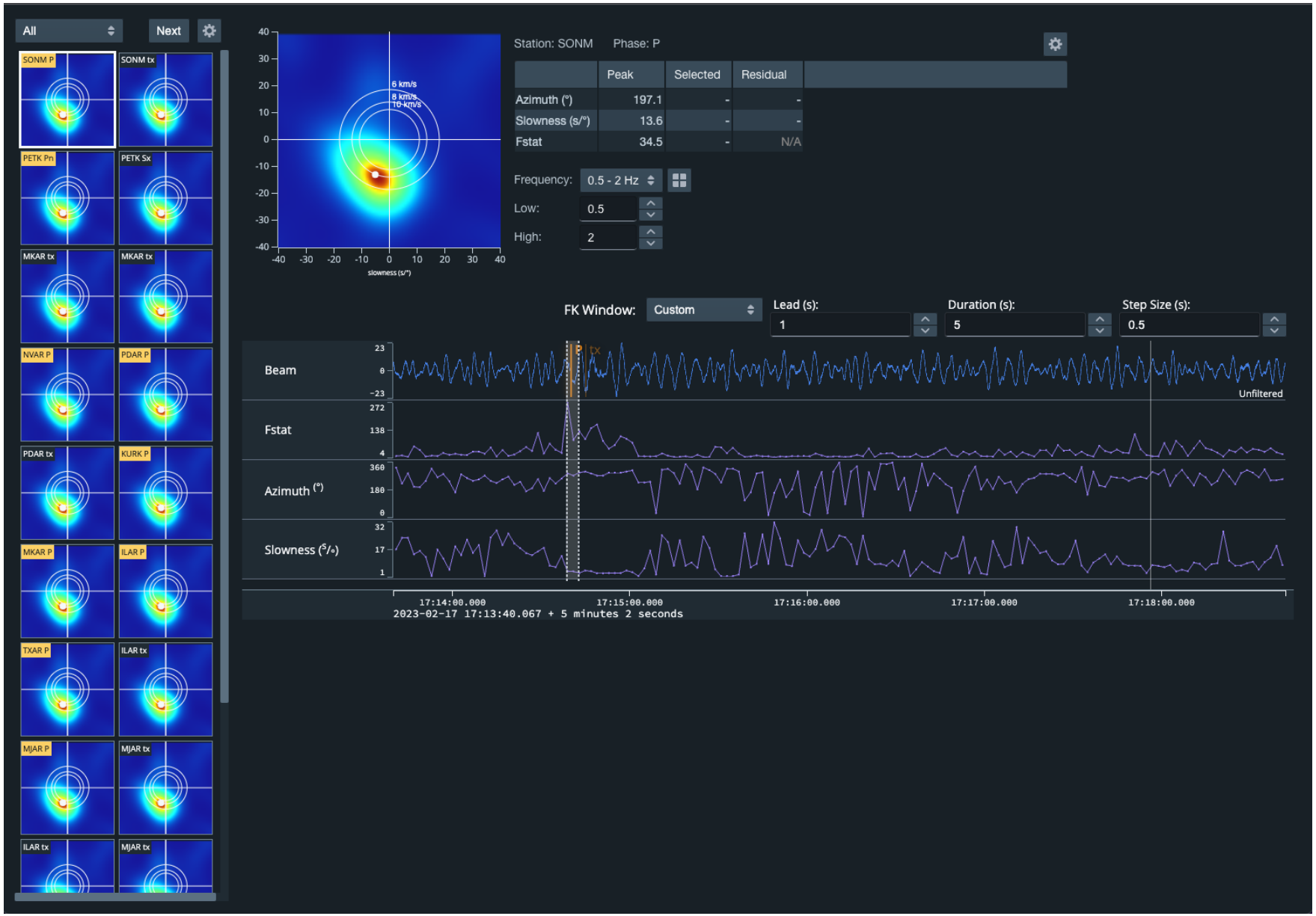
Filters Display

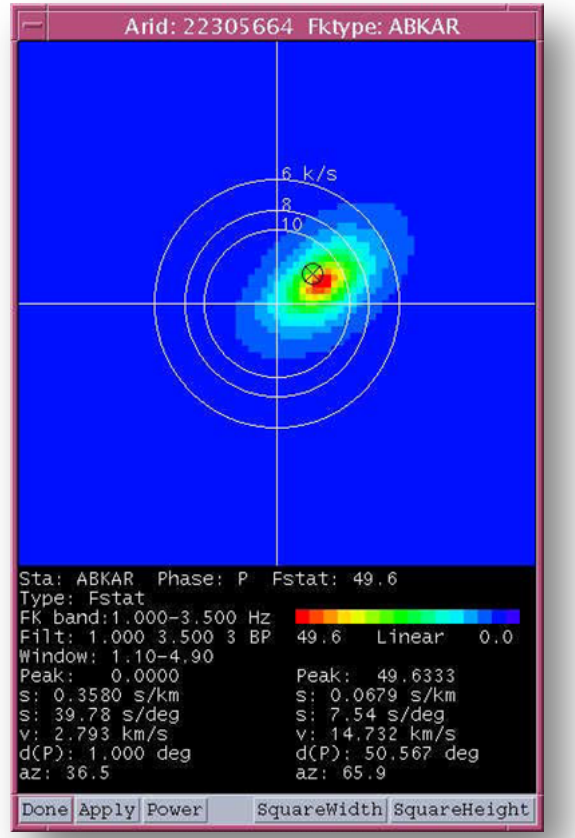
- The Filters display provides a list of available filters that can be applied to the waveforms in the Waveform display. Filters can be uniquely defined for a function (e.g., DETECTION), a high/low/bandpass/band-rejected Butterworth filter, or a cascade of filters.

Filters


WRA beam.BHZ
23.6° / 327.9°
42
0
-42
P
Unfiltered
WRA beam.BHZ
23.6° / 327.9°
3
0
-3
P
DETECTION
WRA beam.BHZ
23.6° / 327.9°
43
0
-43
P
2.0 4.5 3 BR causal
WRA beam.BHZ
23.6° / 327.9°
2
0
-2
P
1.0 5.0 3 BP causal
WRA beam.BHZ
23.6° / 327.9°
0.0
0.0
-0.0
P
Cascade Filter 1

FK (Frequency, wave number) Display (Upcoming)





Legacy

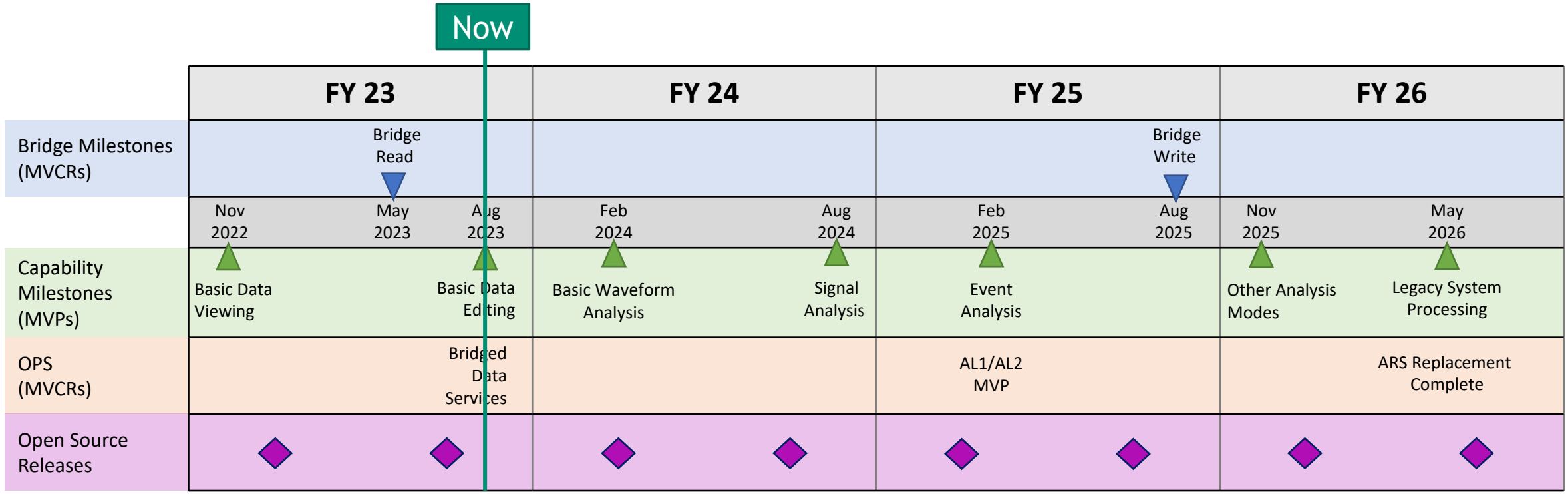
GMS Applications: State-of-Health (SOH)

Station State-of-Health Monitoring

- The latest GMS release also includes a mature, operational-quality Station State-of-Health (SOH) Monitoring capability for CD-1.1 protocol stations, to enhance the ability of system operators to quickly recognize and address station availability and quality issues.
- The US NDC is now deploying this application operationally and the IDC is assessing its capabilities for their operations.

Future Work

GMS Schedule



***MVP**: An early version of the software to deliver or field basic capabilities to users to evaluate and provide feedback on. Insights from MVPs help shape scope, requirements, and design.*
***MVCR**: The initial set of features suitable to be fielded to an operational environment that provides value to the warfighter or end user in a rapid timeline. The MVCR delivers initial warfighting capabilities to enhance some mission outcomes. The MVCR is analogous to a minimum marketable product in commercial industry.*

Conclusions

SNL is developing the GMS for the US NDC, currently focusing on data access services and an Interactive Analysis application to replace ARS. This effort is planned to complete in 2026.

GMS is cloud-ready, operational quality, and secure.

The United States is providing two GMS Open Source software releases per year as a contribution-in-kind for use by IDC Re-engineering.

The current release is available on GitHub:

- https://github.com/SNL-GMS/GMS-PI21-OPEN

The next release should be available early fall 2023, including:

- Final Station SOH Monitoring application
- Significant bridged data access capability
- Early Event Analysis capability

QUESTIONS?