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IDC System Specification Document

Version 1.0

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Abstract

This document contains the system specifications derived to satisfy the system requirements found in the IDC System Requirements Document for the IDC Reengineering Phase 2 project.

Revisions

Version	Date	Author/Team	Revision Description	Authorized by
V1.0	12/2014	IDC Reengineering Project Team	Initial delivery	M. Harris

Contents

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1 INTRODUCTION

1.1 Scope

This System Specification Document (SSD) defines waveform data processing requirements for the International Data Centre (IDC) of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). The IDC applies, on a routine basis, automatic processing methods and interactive analysis to raw International Monitoring System (IMS) data in order to produce, archive, and distribute standard IDC products on behalf of all States Parties. The routine processing includes characterization of events with the objective of screening out events considered to be consistent with natural phenomena or non-nuclear, man-made phenomena. This document does not address requirements concerning acquisition, processing and analysis of radionuclide data but includes requirements for the dissemination of radionuclide data and products.

1.2 Relationship to the US NDC Modernization Project

Like the IDC, the US NDC has begun a project to modernize its waveform processing system. The US NDC and IDC systems are similar in mission functionality and structure, each having evolved from a common early system. These projects are now collaborating to develop a common core architecture. Many IDC specifications benefit from leveraging the specifications developed for US NDC Modernization. The IDC specifications provided here are identified as being common both systems or unique to the IDC.

2 BACKGROUND DOCUMENTS

- IDC Reengineering Phase 2 System Requirements Document, Version 1.1, CTBTO, 19 November 2014
- UN General Assembly A/RES/50/245, Comprehensive Nuclear Test-Ban Treaty, 17 September 1996
- Operational Manual for Hydroacoustic Monitoring and the International Exchange of Hydroacoustic Data, CTBT/WGB/TL-11, 17/16, Latest Revision
- Operational Manual for Infrasound Monitoring and the International Exchange of Infrasound Data, CTBT/WGB/TL-11, 17/17, Latest Revision
- Operational Manual for Seismological Monitoring and the International Exchange of Seismological Data, CTBT/WGB/TL-11, 17/15, Latest Revision
- International Data Centre Draft Operational Manual, CTBT/WGB/TL-11, 17/23, Latest Revision.

3 SYSTEM REQUIREMENTS

3.1 Format

The specifications presented in this System Specifications Document (SSD) satisfy the system requirements described in the IDC System Requirements Document (SRD). SSD requirements are intended to be unitary, complete, consistent, verifiable, and traceable to SRD requirements. SSD requirements generally contain a higher level of detail than SRD requirements. These specifications are traced to requirements in the IDC Reengineering Phase 2 System Requirements Document (SRD). This relationship is shown for each specification in the "Requirements Trace" field and are identified by their SRD-<number>.

Specifications that define a function or attribute of the system are written in the form "The System shall …". These functions may be automatically performed or available for use as needed.

Specifications that define a user interaction with the System are written in the form "The System shall provide the user the capability to . . . ". The term "capability" in this context indicates that the System is required to provide a user interface to perform the defined function. These requirements are written in the same format to identify the requirement as a user interface requirement.

Specifications regarding configuration of processing operations by geographic region facilitate tuning of system performance to adapt to varying earth structure, sensor network coverage, and sources of events.

Specifications numbers are shown in the parenthetical statement after the text of each specification along with the applicability of the specification. The applicability of each specification can be:

- Common – The specification applies to both the IDC Reengineering Phase 2 project and the US NDC Modernization project.
- IDC only – The specification applies to the IDC Reengineering Phase 2 project only.

3.2 Specifications

3.2.1 Data Acquisition

The System hardware and software acquires, organizes, and distributes near-real-time waveform and alphanumeric data from a global sensor network and external monitoring agencies.

3.2.1.1 Data Sources

When a station is added or updated, several configuration parameters are provided which characterize the station and sensors. Station configuration parameters are: station identification, station location, station type, channel configuration, instrument response functions (including the

spatial filter for infrasound stations, which makes the overall response a function of azimuth and vertical slowness), time shift, and calibration information.

3.2.1.1.1 Data Sources Support Interfaces

3.2.1.1.1.1 The System shall provide the System Maintainer the capability to add new stations. (S-1133; Common)
Requirements Trace: SRD-278, SRD-279, SRD-280

3.2.1.1.1.2 The System shall provide the System Maintainer the capability to configure the station instrumentation parameter and sensor deployment. (S-1134; Common)
Requirements Trace: SRD-278, SRD-384

3.2.1.1.1.3 The System shall provide the System Maintainer the capability to enable processing of data from a new station in processing stages without disrupting ongoing processing operations. (S-1135; Common)
Requirements Trace: SRD-278, SRD-280

3.2.1.1.1.4 The System shall provide the System Maintainer the capability to enable acquisition and storage for new station data. (S-1136; Common)
Requirements Trace: SRD-278, SRD-280

3.2.1.1.1.5 The System shall provide the System Maintainer the capability to enable selection for interactive processing for new station data. (S-1137; Common)
Requirements Trace: SRD-278, SRD-280

3.2.1.1.1.6 The System shall provide the System Maintainer the capability to enable station processing for new station data. (S-1138; Common)
Requirements Trace: SRD-278, SRD-280

3.2.1.1.1.7 The System shall provide the System Maintainer the capability to enable network processing for new station data. (S-1139; Common)
Requirements Trace: SRD-278, SRD-280

3.2.1.1.1.8 The System shall provide the System Maintainer the capability to remove stations. (S-1140; Common)
Requirements Trace: SRD-279, SRD-280

3.2.1.1.1.9 The System shall provide the System Maintainer the capability to enable/disable ongoing processing or acquisition operations of data from a station or instrument in processing stages without disrupting ongoing processing operations. (S-1141; Common)
Requirements Trace: SRD-279, SRD-280

3.2.1.1.1.10 The System shall provide the System Maintainer the capability to configure seismic stations as either primary or auxiliary. (S-5606; Common)
Requirements Trace: SRD-432, SRD-433, SRD-434

3.2.1.1.2 Data Sources User Interfaces

3.2.1.1.2.1 The System shall provide the System User the capability to view the station instrumentation, deployment, and configuration parameter values for detection and feature extraction functions. (S-1143; Common)
Requirements Trace: SRD-384, SRD-398

3.2.1.1.2.2 The System shall provide the System User the capability to view information for all configured data sources. (S-1144; Common)
Requirements Trace: SRD-398

3.2.1.1.3 Data Sources Storage

3.2.1.1.3.1 The System shall store station configuration parameters. (S-1146; Common)
Requirements Trace: SRD-172, SRD-189, SRD-512

3.2.1.1.3.2 The System shall store the processing time periods when station configuration parameters are active. (S-1147; Common)
Requirements Trace: SRD-172, SRD-189, SRD-512

3.2.1.2 Data Acquisition Status

The System tracks channel data completeness and real-time data acquisition status of each channel.

Data completeness states are:

1. Missing data is available but has not been received from the station.
2. Incomplete data is not available, i.e. the station was down.
3. Complete data has been received from the station.

Real-time data acquisition status is:

1. Receiving
2. Not receiving

3.2.1.2.1 Data Acquisition Status Support Interfaces

3.2.1.2.1.1 The System shall provide the System User the capability to view the data completeness states of raw channels on the OPS Subsystem Data Acquisition Partition. (S-1150; Common)
Requirements Trace: SRD-11

3.2.1.2.1.2 The System shall provide the System User the capability to view the data completeness states of raw channels on the OPS Subsystem Data Processing Partition. (S-1151; Common)
Requirements Trace: SRD-11

3.2.1.2.1.3 The System shall provide the System User the capability to view the data completeness states of raw channels on the ALT Subsystem Data Acquisition Partition. (S-

1152; Common)
Requirements Trace: SRD-11

3.2.1.2.1.4 The System shall provide the System User the capability to view the data completeness states of raw channels on the ALT Subsystem Data Processing Partition. (S-1153; Common)
Requirements Trace: SRD-11

3.2.1.2.1.5 The System shall provide the System User the capability to view the real-time data acquisition status of raw channels. (S-1154; Common)
Requirements Trace: SRD-12

3.2.1.2.1.6 The System shall provide the System User the capability to view the real-time mission capability state of each station. (S-1155; Common)
Requirements Trace: SRD-12

3.2.1.2.2 Data Acquisition Status User Interfaces

3.2.1.2.2.1 The System shall update analyst displays with newly acquired waveform data within 1 minute of acquisition. (S-1157; Common)
Requirements Trace: SRD-130, SRD-131

3.2.1.2.2.2 The System shall notify the user within 1 minute of acquisition when new waveform data arrives during a waveform analysis session that is relevant to that session. (S-1158; Common)
Requirements Trace: SRD-131

3.2.1.2.2.3 The System shall notify the user within 1 minute of acquisition when new alphanumeric data becomes available during a waveform analysis session that is relevant to that session. (S-1159; Common)
Requirements Trace: SRD-131

3.2.1.3 Data Acquisition Control
The System acquires station data through multiple paths. All station data must be available on both the OPS and ALT Subsystems. The System Maintainer controls station data routing to either the OPS Subsystem or the ALT Subsystem. The OPS and ALT Subsystems then exchange data so both Subsystems have the complete set of station data. Some station data is available from multiple sources. The System notifies the System Maintainer when the System detects that a station has stopped sending data and a secondary source for the data exists so the System Maintainer can reconfigure the station data routing to acquire the data from the secondary source.

3.2.1.3.1 Data Acquisition Control Processing

3.2.1.3.1.1 The System shall provide data buffering allowing acceptance of waveform data arriving a minimum of 10 days after its recording at a station. (S-5580; IDC only)
Requirements Trace: SRD-436

3.2.1.3.1.2 The System shall complete transfer of waveform data from the data acquisition partition to the data processing partition within 5 minutes of receipt of the data. (S-5785; IDC only)
Requirements Trace: SRD-441

3.2.1.3.1.3 The data processing partition shall request auxiliary seismic waveform data from the data acquisition partition. (S-5611; IDC only)
Requirements Trace: SRD-438

3.2.1.3.1.4 The System shall acquire continuous waveform data from hydroacoustic, infrasound, and primary seismic stations of the IMS Network. (S-5577; IDC only)
Requirements Trace: SRD-430

3.2.1.3.1.5 The System shall request waveform data segments from auxiliary seismic stations of the IMS network. (S-5578; IDC only)
Requirements Trace: SRD-432, SRD-434

3.2.1.3.1.6 The System shall acquire waveform data from auxiliary seismic stations of the IMS Network. (S-5607; IDC only)
Requirements Trace: SRD-432

3.2.1.3.1.7 The System shall acquire continuous waveform data from hydroacoustic, infrasound, and primary seismic stations of the IMS Network. (S-5609; IDC only)
Requirements Trace: SRD-433

3.2.1.3.1.8 The System shall acquire all ISC bulletin products (S-5584; IDC only)
Requirements Trace: SRD-15

3.2.1.3.1.9 The System shall accept event bulletin data from External Data Centers. (S-5585; Common)
Requirements Trace: SRD-15

3.2.1.3.1.10 The System shall accept event bulletin data in new formats. (S-1241; Common)
Requirements Trace: SRD-15

3.2.1.3.1.11 The System shall be able to easily store external event bulletins from new sources. (S-1177; Common)
Requirements Trace: SRD-174

3.2.1.3.1.12 The data processing partition shall access and process all waveform data stored on the system. (S-5610; IDC only)
Requirements Trace: SRD-438

3.2.1.3.1.13 The system shall request global meteorological data from specified sources within 10 minutes of its availability. (S-5759; Common)
Requirements Trace: SRD-600

3.2.1.3.1.14 The system shall request global meteorological data (3D wind and temperature) from specified sources spanning the altitude range of 0 km (sea level) to 120 km above sea level. (S-5623; Common)
Requirements Trace: SRD-411

3.2.1.3.1.15 The system shall convert global meteorological data received in pressure coordinate format into altitude coordinate format. (S-5624; Common)
Requirements Trace: SRD-411, SRD-412, SRD-600

3.2.1.3.1.16 The system shall compute data availability metrics for data acquisition as specified in the IDC Operational Manual. (S-5622; IDC only)
Requirements Trace: SRD-442

3.2.1.3.2 Data Acquisition Control Support Interfaces

3.2.1.3.2.1 The System shall provide the Analyst the capability to access and view all waveform data stored on the System. (S-1878; Common)
Requirements Trace: SRD-124, SRD-136, SRD-171, SRD-218, SRD-438

3.2.1.3.2.2 The System shall provide the System Controller the capability to select the stations providing data to ALT Subsystem. (S-1179; Common)
Requirements Trace: SRD-432, SRD-433, SRD-434

3.2.1.3.2.3 The System shall provide the System Controller the capability to start acquiring data from one or more stations. (S-1180; Common)
Requirements Trace: SRD-13

3.2.1.3.2.4 The System shall provide the System Controller the capability to stop acquiring data from one or more stations. (S-1181; Common)
Requirements Trace: SRD-13

3.2.1.3.2.5 The System shall provide the System Controller the capability to select the stations providing data to OPS Subsystem. (S-1182; Common)
Requirements Trace: SRD-432

3.2.1.3.2.6 The System shall provide the System Controller the capability to request re-transmission of missing data from stations. (S-1186; Common)
Requirements Trace: SRD-493

3.2.1.3.3 Data Acquisition Control User Interfaces

3.2.1.3.3.1 The System shall provide the System User the capability to view acquired station State-of-Health data. (S-1189; Common)
Requirements Trace: SRD-124, SRD-136

3.2.1.3.3.2 The System shall provide the Analyst the capability to request auxiliary seismic waveform data from the data acquisition partition. (S-5612; IDC only)
Requirements Trace: SRD-438

3.2.1.3.4 Data Acquisition Control Storage

3.2.1.3.4.1 The System shall store all raw waveform data. (S-1191; Common)
Requirements Trace: SRD-171, SRD-611

3.2.1.3.4.2 The System shall store acquired waveform data in its originating format. (S-1192; Common)
Requirements Trace: SRD-611

3.2.1.3.4.3 The System shall store IDC event bulletin data. (S-1195; IDC only)
Requirements Trace: SRD-174, SRD-189

3.2.1.3.4.4 The System shall store all data that are available for external release on the data acquisition partition. (S-5625; Common)
Requirements Trace: SRD-431

3.2.1.4 Data Authentication

3.2.1.4.1 Data Authentication Processing

3.2.1.4.1.1 The System shall authenticate the digital signature using PKI credentials upon receipt of signed station waveform data. (S-1199; Common)
Requirements Trace: SRD-9

3.2.1.4.1.2 The System shall use PKI to digitally authenticate data requests received from an External Data Center. (S-5613; IDC only)
Requirements Trace: SRD-21

3.2.1.4.1.3 The System shall use PKI to digitally authenticate data requests received from the Authorized External User. (S-5614; IDC only)
Requirements Trace: SRD-21

3.2.1.4.1.4 The System shall perform retrospective authentication on signed waveform data. (S-1203; Common)
Requirements Trace: SRD-10

3.2.1.4.1.5 The System shall allow for PKI credential changes without interrupting operations if made prior to key expiration. (S-1204; Common)
Requirements Trace: SRD-9

3.2.1.4.1.6 The System shall mark acquired waveform data as unauthenticated when the data cannot be authenticated. (S-1205; Common)
Requirements Trace: SRD-9

3.2.1.4.2 Data Authentication Support Interfaces

3.2.1.4.2.1 The System shall provide the System Controller the capability to generate and install PKI credentials. (S-1207; Common)
Requirements Trace: SRD-9

3.2.1.4.2.2 The System shall notify the System Controller of expiring PKI credentials a minimum of five (5) days prior to key expiration. (S-1208; Common)
Requirements Trace: SRD-9

3.2.1.4.3 Data Authentication Storage

3.2.1.4.3.1 The System shall store all PKI credentials used to digitally sign station waveform data. (S-1210; Common)
Requirements Trace: SRD-10, SRD-179

3.2.1.5 Data Forwarding

3.2.1.5.1 Data Forwarding Processing

3.2.1.5.1.1 The System shall automatically forward data in near-real time in the CD1.1 format. (S-1220; Common)
Requirements Trace: SRD-22

3.2.1.5.1.2 The System shall convert station configuration data to Station/FDSNXML format. (S-5706; IDC only)
Requirements Trace: SRD-505

3.2.1.5.1.3 The System shall convert station configuration data to SeisComP3XML format. (S-5707; IDC only)
Requirements Trace: SRD-505

3.2.1.5.1.4 The System shall provide an extensible architecture for the distribution of new data and reports. (S-5710; Common)
Requirements Trace: SRD-409, SRD-505

3.2.1.5.2 Data Forwarding Support Interfaces

3.2.1.5.3 Data Forwarding User Interfaces

3.2.1.5.3.1 The System shall provide the Authorized External User the capability to request the System to forward reports. (S-1226; Common)
Requirements Trace: SRD-163, SRD-507

3.2.1.5.3.2 The System shall provide the Authorized External User the capability to request the System to send station configuration data at user defined time intervals. (S-2576; Common)
Requirements Trace: SRD-507

3.2.1.5.3.3 The System shall provide the Authorized External User the capability to request the System to send station SOH data at user defined time intervals. (S-2578; Common)
Requirements Trace: SRD-507

3.2.1.5.3.4 The System shall provide the Authorized External User the capability to request the System to send reports at user defined time intervals. (S-2579; Common)
Requirements Trace: SRD-507

3.2.1.5.3.5 The System shall provide the Authorized External User the capability to request the System to send event bulletins at user defined time intervals. (S-2580; Common)
Requirements Trace: SRD-507

3.2.1.5.3.6 The System shall provide the Authorized External User the capability to request the System to send station configuration data when there is a change in that data. (S-2581; Common)
Requirements Trace: SRD-507

3.2.1.5.3.7 The System shall provide the Authorized External User the capability to request the System to send station data acquisition statistics when there is a change in those statistics. (S-2582; Common)
Requirements Trace: SRD-507

3.2.1.5.3.8 The System shall provide the Authorized External User the capability to request the System to send station SOH data when there is a change in that data. (S-2583; Common)
Requirements Trace: SRD-507

3.2.1.5.3.9 The System shall provide the Authorized External User the capability to request the System to send reports when there is a change in those reports. (S-2584; Common)
Requirements Trace: SRD-507

3.2.1.5.3.10 The System shall provide the Authorized External User the capability to request the System to send event bulletins when there is a change in those event bulletins. (S-2585; Common)
Requirements Trace: SRD-507

3.2.1.5.3.11 The System shall provide the Authorized External User the capability to request station configuration data in the Station/FDSNXML format. (S-5704; IDC only)
Requirements Trace: SRD-505

3.2.1.5.3.12 The System shall provide the Authorized External User the capability to request station configuration data in the SeisComP3XML format. (S-5705; IDC only)
Requirements Trace: SRD-505

3.2.1.5.3.13 The System shall provide the Authorized External User the capability to request the System to send waveform data at user defined time intervals. (S-1225; Common)
Requirements Trace: SRD-505

3.2.1.5.3.14 The System shall provide the System Controller the capability to select the station data forwarded to each internal destination. (S-1227; Common)
Requirements Trace: SRD-22

3.2.1.5.3.15 The System shall provide the System Controller the capability to select the station data forwarded to each external destination. (S-1228; Common)
Requirements Trace: SRD-22

3.2.1.5.3.16 The System shall provide the Authorized External User the capability to view station data acquisition statistics via a web site. (S-1229; Common)
Requirements Trace: SRD-25

3.2.1.5.3.17 The System shall provide the System User the capability to view station data acquisition statistics via a web site. (S-5581; Common)
Requirements Trace: SRD-25

3.2.1.5.3.18 The System shall provide the System User the capability to view the authentication status of waveform data. (S-5582; Common)
Requirements Trace: SRD-25

3.2.1.5.3.19 The System shall provide the System User the capability to view information about forwarded waveform data. (S-5583; Common)
Requirements Trace: SRD-25

3.2.1.5.3.20 The System shall provide the System Controller the capability to select the destinations of forwarded waveform data. (S-5781; Common)
Requirements Trace: SRD-22

3.2.1.5.3.21 The System shall provide the System Controller the capability to select the bulletins forwarded to each internal destination. (S-5782; Common)
Requirements Trace: SRD-22

3.2.1.5.3.22 The System shall provide the System Controller the capability to select the bulletins forwarded to each external destination. (S-5783; Common)
Requirements Trace: SRD-22

3.2.1.5.3.23 The System shall provide the System Controller the capability to select the destinations of forwarded bulletins. (S-5784; Common)
Requirements Trace: SRD-22

3.2.1.6 Waveform Formats

3.2.1.6.1 Waveform Formats Processing

3.2.1.6.1.1 The System shall accept waveform data in the CD1.1 format. (S-1234; Common)
Requirements Trace: SRD-611

3.2.1.6.1.2 The System shall accept waveform data in the CD1.0 format. (S-1235; Common)
Requirements Trace: SRD-611

3.2.1.6.1.3 The System shall accept waveform data in the CSS3.0 format. (S-1236; Common)
Requirements Trace: SRD-611

3.2.1.6.1.4 The System shall accept waveform data in the SEED format. (S-1237; Common)
Requirements Trace: SRD-611

3.2.1.6.1.5 The System shall accept waveform data in the mini-SEED format. (S-1238; Common)
Requirements Trace: SRD-611

3.2.1.6.1.6 The System shall accept waveform data in the Antelope format. (S-1239; Common)
Requirements Trace: SRD-611

3.2.1.6.1.7 The System shall accept waveform data in new formats. (S-1240; Common)
Requirements Trace: SRD-611

3.2.1.6.1.8 The System shall convert waveform data to the SEED format. (S-1242; Common)
Requirements Trace: SRD-505

3.2.1.6.1.9 The System shall convert waveform data to the CSS 3.0 format. (S-1243; Common)
Requirements Trace: SRD-505

3.2.1.6.1.10 The System shall convert waveform data to the GSE2.1/IMS1.0 format. (S-1245; Common)
Requirements Trace: SRD-505

3.2.1.6.2 Waveform Formats User Interfaces

3.2.1.6.2.1 The System shall provide the Authorized External User the capability to request waveform data in the SEED format. (S-1247; Common)
Requirements Trace: SRD-616

3.2.1.6.2.2 The System shall provide the Authorized External User the capability to request waveform data in the CSS 3.0 format. (S-1248; Common)
Requirements Trace: SRD-616

3.2.1.6.2.3 The System shall provide the Authorized External User the capability to request waveform data in the GSE2.1/IMS1.0 format. (S-1250; Common)

3.2.2 Waveform Quality Control

The System's waveform data may contain errors caused by recording or transmission problems. Waveform Quality Control processing identifies waveform sections containing errors and marks those sections with Waveform Quality Control Masks (Waveform QC Masks). Each Waveform QC Mask has a defined start time and end time delimiting the waveform section marked and potentially removed from processing. If configured, the System does not use waveform sections marked with Waveform QC Masks during waveform processing.

3.2.2.1 Waveform Quality Control Processing

3.2.2.1.1 The System shall automatically identify waveforms containing repairable data gaps. (S-1253; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.2 The System shall automatically identify waveforms containing long data gaps. (S-5592; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.3 The System shall automatically create a Waveform QC Mask for a waveform containing a data gap. (S-1254; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.4 The System shall automatically identify waveforms containing amplitude spikes. (S-1255; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.5 The System shall automatically create a Waveform QC Mask for a waveform containing an amplitude spike. (S-1256; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.6 The System shall automatically identify waveforms containing repeated adjacent amplitude values. (S-1257; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.7 The System shall automatically create a Waveform QC Mask for a waveform containing a repeated amplitude value data error. (S-1258; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.8 The System shall automatically identify waveforms containing linear trends in amplitude. (S-1259; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.9 The System shall automatically fit linear trends to waveform data. (S-1260; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.10 The System shall automatically create a Waveform QC Mask for a waveform containing a waveform linear trend data error. (S-1261; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.11 The System shall automatically create a Waveform QC Mask for a waveform containing a calibration signal. (S-1262; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.12 The System shall automatically create a Waveform QC Mask for a waveform containing invalid gain. (S-1264; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.13 The System shall automatically identify the percent of data samples in a waveform section containing data errors. (S-1265; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.14 The System shall automatically create a Waveform QC Mask for a waveform section containing errors in more than the allowed percentage of data samples. (S-1266; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.15 The System shall maximize the length of a Waveform QC Mask created for a waveform section containing errors in more than the allowed percentage of data samples. (S-1267; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.16 The System shall begin a Waveform QC Mask created for a waveform section containing errors in more than the allowed percentage of data samples on a sample containing a data error. (S-1268; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.17 The System shall terminate an automatically created Waveform QC Mask when the condition leading to the creation of that Waveform QC Mask is no longer satisfied. (S-1269; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.18 The System shall use State-of-Health information acquired from stations to identify waveform sections known to contain data errors and create Waveform QC Masks for those sections. (S-1270; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.1.19 The System shall create a Waveform QC Mask for a channel from a multichannel station containing noisy data relative to the other channels from that station. (S-1271; Common)
Requirements Trace: SRD-29, SRD-54, SRD-406

3.2.2.1.20 The System shall create a Waveform QC Mask for a channel containing noisy data relative to a global noise model. (S-5593; Common)
Requirements Trace: SRD-29, SRD-54, SRD-406

3.2.2.1.21 The System shall create a Waveform QC Mask for a channel containing noisy data relative to a station noise model. (S-5594; Common)
Requirements Trace: SRD-29, SRD-54, SRD-406

3.2.2.1.22 The System shall create Waveform QC Masks with times in the future. (S-1272; Common)
Requirements Trace: SRD-31

3.2.2.1.23 The System shall not use waveform sections containing configured Waveform QC Masks during waveform processing. (S-1273; Common)
Requirements Trace: SRD-33

3.2.2.2 Waveform Quality Control Support Interfaces

3.2.2.2.1 The System shall provide the System Maintainer the capability to configure the minimum change in amplitude with respect to time that is automatically recognized as an amplitude spike. (S-1275; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.2.2 The System shall provide the System Maintainer the capability to configure the minimum number of equal, consecutive amplitude values required for automatic recognition of a repeated amplitude value data error. (S-1276; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.2.3 The System shall provide the System Maintainer the capability to configure the maximum percent of data samples in a waveform section allowed to contain data errors. (S-1278; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.2.4 The System shall provide the System Maintainer the capability to configure Waveform QC Mask processing parameters on a per station basis. (S-5595; IDC only)
Requirements Trace: SRD-29, SRD-406

3.2.2.2.5 The System shall provide the System Maintainer the capability to configure the execution order of Waveform QC Mask application on a per sensor basis. (S-1280; Common)
Requirements Trace: SRD-29, SRD-406

3.2.2.2.6 The System shall provide the System Maintainer the capability to configure the maximum time length in the future for user created Waveform QC Masks. (S-1281; Common)
Requirements Trace: SRD-31

3.2.2.2.7 The System shall provide the System Maintainer the capability to authorize a System User to create Waveform QC masks extending into the future. (S-1282; Common)
Requirements Trace: SRD-31

3.2.2.3 Waveform Quality Control User Interfaces

3.2.2.3.1 The System shall provide the Analyst the capability to view Waveform QC Masks. (S-1284; Common)
Requirements Trace: SRD-33, SRD-34, SRD-124, SRD-136, SRD-444

3.2.2.3.2 The System shall provide the Analyst the capability to view the Waveform QC Masks that were active at a user specified date and time. (S-1285; Common)
Requirements Trace: SRD-30, SRD-34, SRD-124, SRD-136, SRD-407, SRD-444

3.2.2.3.3 The System shall provide the Analyst the capability to create a Waveform QC Mask for a selected channel and time interval. (S-1286; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.4 The System shall provide the Analyst the capability to modify Waveform QC Masks. (S-1287; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.5 The System shall provide the Analyst the capability to remove Waveform QC Masks. (S-1288; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.6 The System shall provide the Analyst the capability to enter rationale for creating a Waveform QC Mask. (S-1289; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.7 The System shall provide the Analyst the capability to enter rationale for modifying a Waveform QC Mask. (S-1290; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.8 The System shall provide the Analyst the capability to enter rationale for removing a Waveform QC Mask. (S-1291; Common)
Requirements Trace: SRD-30, SRD-124, SRD-136, SRD-407

3.2.2.3.9 The System shall provide the System User the capability to compare Waveform QC Masks generated by each processing stage for selected points in the processing history. (S-1292; Common)
Requirements Trace: SRD-124, SRD-136, SRD-237

3.2.2.3.10 The System shall provide the System User the capability to compare Waveform QC Masks generated by each Subsystem for selected points in the processing history. (S-1293; Common)
Requirements Trace: SRD-124, SRD-136, SRD-237

3.2.2.3.11 The System shall provide an authorized System User the capability to create a Waveform QC Mask extending into the future. (S-1294; Common)
Requirements Trace: SRD-31

3.2.2.4 Waveform Quality Control Storage

3.2.2.4.1 The System shall store the processing time period(s) during which each Waveform QC Mask was applied to the underlying waveform data. (S-1296; Common)
Requirements Trace: SRD-33, SRD-172, SRD-189

3.2.2.4.2 The System shall store the Waveform QC Masks applied to the waveform data used for each waveform processing operation. (S-1297; Common)
Requirements Trace: SRD-33, SRD-172, SRD-189, SRD-444

3.2.2.4.3 The System shall store the channel masked by each Waveform QC Mask. (S-1298; Common)
Requirements Trace: SRD-30, SRD-172, SRD-189

3.2.2.4.4 The System shall store the identity of the user or processing stage creating each Waveform QC Mask. (S-1299; Common)
Requirements Trace: SRD-30, SRD-189

3.2.2.4.5 The System shall store the identity of the user or processing stage modifying each Waveform QC Mask. (S-1300; Common)
Requirements Trace: SRD-30, SRD-189

3.2.2.4.6 The System shall store the identity of the user or processing stage removing each Waveform QC Mask. (S-1301; Common)
Requirements Trace: SRD-30, SRD-189

3.2.2.4.7 The System shall store the time of each Waveform QC Mask creation. (S-1302; Common)
Requirements Trace: SRD-32, SRD-189

3.2.2.4.8 The System shall store the time of each Waveform QC Mask removal. (S-1303; Common)
Requirements Trace: SRD-32, SRD-189

3.2.2.4.9 The System shall store the time of each Waveform QC Mask modification. (S-1304; Common)
Requirements Trace: SRD-32, SRD-189

3.2.2.4.10 The System shall store the type of error being masked for each automatically created Waveform QC Mask. (S-1305; Common)
Requirements Trace: SRD-32, SRD-172, SRD-189, SRD-492

3.2.2.4.11 The System shall store the Analyst's rationale for creating a Waveform QC Mask. (S-1306; Common)
Requirements Trace: SRD-30, SRD-136, SRD-189

3.2.2.4.12 The System shall store the Analyst's rationale for modifying a Waveform QC Mask. (S-1307; Common)
Requirements Trace: SRD-30, SRD-136, SRD-189

3.2.2.4.13 The System shall store the Analyst's rationale for removing a Waveform QC Mask. (S-1308; Common)
Requirements Trace: SRD-30, SRD-136, SRD-189

3.2.3 Signal Enhancement
Waveform processing performed to enhance event signals while suppressing background noise. The System creates derived channels from raw channel inputs by filtering, rotating, or beaming input channels.

3.2.3.1 Waveform Filtering

3.2.3.1.1 Waveform Filtering Processing

3.2.3.1.1.1 The System shall provide a waveform filter library containing commonly used filters. (S-1312; Common)
Requirements Trace: SRD-38

3.2.3.1.1.2 The System shall filter waveforms using the coefficients from the numerator and denominator of the filter's transfer function. (S-1313; Common)
Requirements Trace: SRD-38

3.2.3.1.1.3 The System shall downsample waveforms (filter and decimate). (S-1314; Common)
Requirements Trace: SRD-38

3.2.3.1.1.4 The System shall apply a constant phase offset while downsampling waveforms. (S-1315; Common)
Requirements Trace: SRD-38

3.2.3.1.1.5 The System shall upsample waveforms. (S-1316; Common)
Requirements Trace: SRD-38

3.2.3.1.1.6 The System shall apply a constant phase offset while upsampling waveforms. (S-1317; Common)
Requirements Trace: SRD-38

3.2.3.1.1.7 The System shall cascade up to 10 filters. (S-1318; Common)
Requirements Trace: SRD-38, SRD-62, SRD-448

3.2.3.1.1.8 The System shall convert analog filter transfer functions to digital filter transfer functions. (S-1319; Common)
Requirements Trace: SRD-38

3.2.3.1.1.9 The System shall compute the time shift of a filter's group delay from the coefficients of that filter's transfer function. (S-1320; Common)
Requirements Trace: SRD-39

3.2.3.1.1.10 The System shall shift filter output waveforms to remove filter group delay. (S-1321; Common)
Requirements Trace: SRD-39

3.2.3.1.1.11 The System shall automatically shift waveforms to remove recording instrument response delay. (S-1322; Common)
Requirements Trace: SRD-39

3.2.3.1.1.12 The System shall remove recording instrument response from waveforms. (S-1323; Common)
Requirements Trace: SRD-38

3.2.3.1.1.13 The System shall remove a waveform's DC offset. (S-1324; Common)
Requirements Trace: SRD-38

3.2.3.1.1.14 The System shall convert amplitude measurements from measured counts to earth displacement. (S-1326; Common)
Requirements Trace: SRD-62

3.2.3.1.1.15 The System shall convert amplitude measurements from measured counts to velocity. (S-5631; Common)
Requirements Trace: SRD-62

3.2.3.1.1.16 The System shall convert amplitude measurements from measured counts to acceleration. (S-5632; Common)
Requirements Trace: SRD-62

3.2.3.1.1.17 The System shall not apply a filter to any waveform for which the difference between the filter’s sample rate and the waveform’s sample rate is greater than the filter’s sample rate tolerance. (S-1327; Common)
Requirements Trace: SRD-38

3.2.3.1.2 Waveform Filtering Support Interfaces

3.2.3.1.2.1 The System shall provide the System Maintainer the capability to configure waveform filters by channel. (S-2418; Common)
Requirements Trace: SRD-38

3.2.3.1.3 Waveform Filtering User Interfaces

3.2.3.1.3.1 The System shall provide the Analyst the capability to design a Butterworth filter. (S-1334; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.2 The System shall provide the Analyst the capability to design a Pseudo Correlation filter. (S-1335; Common)
Requirements Trace: SRD-38, SRD-62, SRD-124, SRD-136, SRD-448

3.2.3.1.3.3 The System shall provide the Analyst the capability to design a Phase Match filter. (S-1336; Common)
Requirements Trace: SRD-38, SRD-62, SRD-124, SRD-136, SRD-448

3.2.3.1.3.4 The System shall provide the Analyst the capability to design an autoregressive filter. (S-1337; Common)
Requirements Trace: SRD-38, SRD-62, SRD-124, SRD-136, SRD-448

3.2.3.1.3.5 The System shall provide the Analyst the capability to design a filter by directly specifying the coefficients of the numerator and denominator of the filter's transfer function. (S-1338; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.6 The System shall provide the Analyst the capability to enter textual descriptions for user designed waveform filters. (S-1339; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.7 The System shall provide the Analyst the capability to view filtered waveforms. (S-1340; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.8 The System shall provide the Analyst the capability to view predefined waveform filter parameters. (S-1341; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.9 The System shall provide the Analyst the capability to apply predefined filters to selected waveforms. (S-1342; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.10 The System shall provide the Analyst the capability to design filter cascades. (S-1343; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.11 The System shall notify the Analyst when a filter is not applied to a waveform because the difference between the filter's sample rate and the waveform's sample rate is greater than the filter's sample rate tolerance. (S-1344; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.12 The System shall provide the Researcher the capability to decimate waveforms. (S-1331; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.13 The System shall provide the Researcher the capability to interpolate waveforms. (S-1332; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.3.14 The System shall provide the Researcher the capability to resample waveforms. (S-1333; Common)
Requirements Trace: SRD-38, SRD-124, SRD-136

3.2.3.1.4 Waveform Filtering Storage

3.2.3.1.4.1 The System shall store a textual description with each waveform filter. (S-1346; Common)
Requirements Trace: SRD-38, SRD-189

3.2.3.1.4.2 The System shall store filters using the coefficients of the numerator and denominator of the filter's transfer function. (S-1347; Common)
Requirements Trace: SRD-38

3.2.3.2 Waveform Rotation
Data from a three component seismometer is rotated to the signal's angle of arrival to form traces that correspond to radial and transverse ground motion.

3.2.3.2.1 Waveform Rotation Processing

3.2.3.2.1.1 The System shall rotate the components of 3-component seismic waveform data from one 3-dimensional coordinate system to another 3-dimensional coordinate system. (S-1350; Common)
Requirements Trace: SRD-382

3.2.3.2.2 Waveform Rotation Support Interfaces

3.2.3.2.2.1 The System shall provide the System Maintainer the capability to configure 3-component seismic waveform rotations by station. (S-2422; Common)
Requirements Trace: SRD-382

3.2.3.2.3 Waveform Rotation User Interfaces

3.2.3.2.3.1 The System shall provide the Analyst the capability to rotate the components of 3-component seismic waveform data to any Analyst specified 3-dimensional coordinate system. (S-1352; Common)
Requirements Trace: SRD-124, SRD-136, SRD-382

3.2.3.2.3.2 The System shall provide the Analyst the capability to rotate the components of 2-component horizontal seismic waveform data to any Analyst specified azimuth. (S-1353;

Common)
Requirements Trace: SRD-124, SRD-136, SRD-382

3.2.3.3 Beamforming
Beamforming is a multichannel signal processing technique that focuses the elements of an array in a specific direction. This provides a signal to noise ratio gain via constructive interference of coherent directional signals and destructive interference of incoherent background noise. Beam definition parameters are: channels forming the beam, time interval, waveform filter, beam type (fk, origin, or detection), azimuth targeted by the beam, slowness targeted by the beam, phase targeted by the beam, whether or not the beam is coherent, travel time model and travel time uncertainty model used to predict signal arrival times.

3.2.3.3.1 Beamforming Processing

3.2.3.3.1.1 The System shall create beams using a specified set of channels. (S-1356; Common)
Requirements Trace: SRD-384

3.2.3.3.1.2 The System shall form coherent beams. (S-1357; Common)
Requirements Trace: SRD-384

3.2.3.3.1.3 The System shall form incoherent beams. (S-1358; Common)
Requirements Trace: SRD-384

3.2.3.3.1.4 The System shall form beams for specified time windows. (S-1359; Common)
Requirements Trace: SRD-384

3.2.3.3.1.5 The System shall form beams for specified azimuth and slowness pairs. (S-1360; Common)
Requirements Trace: SRD-384

3.2.3.3.1.6 The System shall compute continuous beams for virtual event hypotheses for predefined geographic regions. (S-1361; Common)
Requirements Trace: SRD-144

3.2.3.3.1.7 The System shall account for differences in array element sensor vertical position when forming beams. (S-1362; Common)
Requirements Trace: SRD-384

3.2.3.3.1.8 The System shall filter waveform data from individual channels before beam forming to make channel frequency content consistent across all channels in the beam. (S-1363; Common)
Requirements Trace: SRD-384

3.2.3.3.1.9 The System shall convert individual channels from measured counts to earth displacement before using the channels to form beams. (S-1364; Common)
Requirements Trace: SRD-384

3.2.3.3.1.10 The System shall first rotate 3-component data from each seismic array element before beaming to form radial origin beams for 3-component seismic arrays. (S-1365; Common)
Requirements Trace: SRD-382, SRD-384

3.2.3.3.1.11 The System shall first rotate 3-component data from each seismic array element before beaming to form transverse origin beams for 3-component seismic arrays. (S-1366; Common)
Requirements Trace: SRD-382, SRD-384

3.2.3.3.1.12 The System shall first rotate 3-component data from each seismic array element before beaming to form radial fk-beams for 3-component seismic arrays. (S-1367; Common)
Requirements Trace: SRD-382, SRD-384

3.2.3.3.1.13 The System shall first rotate 3-component data from each seismic array element before beaming to form transverse fk-beams for 3-component seismic arrays. (S-1368; Common)
Requirements Trace: SRD-382, SRD-384

3.2.3.3.1.14 The System shall create an origin beam steered to an event hypothesis' hypocenter and a seismic array station's predicted first P arrival time whenever a seismic array station lacks a first P signal detection association. (S-1405; Common)
Requirements Trace: SRD-447

3.2.3.3.1.15 The System shall create beams for each event steered to the predicted azimuth and slowness for configured phases that are not associated to the event. (S-5788; Common)
Requirements Trace: SRD-447

3.2.3.3.1.16 The System shall automatically generate fk spectra from array station waveform data when a signal detection occurs at an array element. (S-1403; Common)
Requirements Trace: SRD-384, SRD-446

3.2.3.3.1.17 The System shall automatically generate a beam for the vector corresponding to the fk spectrum peak for a detection. (S-1404; Common)
Requirements Trace: SRD-384, SRD-446

3.2.3.3.1.18 The System shall create beams steered to the measured azimuth and slowness for all signal detections created for primary seismic array stations. (S-5787; IDC only)
Requirements Trace: SRD-446

3.2.3.3.2 Beamforming Support Interfaces

3.2.3.3.2.1 The System shall provide the System Maintainer the capability to configure array station beams by station (S-2424; Common)
Requirements Trace: SRD-384

3.2.3.3.2.2 The System shall provide the System Maintainer the capability to configure for which phases and stations to automatically create origin beams. (S-5789; Common)
Requirements Trace: SRD-447

3.2.3.3.3 Beamforming User Interfaces

3.2.3.3.3.1 The System shall notify the Analyst when the channels selected for a beam measure inconsistent types of ground motion. (S-1370; Common)
Requirements Trace: SRD-136, SRD-384

3.2.3.3.3.2 The System shall notify the Analyst when any two channels selected for a beam have sample rates that differ by more than the beam's sample rate tolerance. (S-1371; Common)
Requirements Trace: SRD-124, SRD-136, SRD-384

3.2.3.3.3.3 The System shall provide the Analyst the capability to view continuous beams. (S-1372; Common)
Requirements Trace: SRD-124, SRD-136

3.2.3.3.3.4 The System shall provide the Analyst the capability to view continuous beams for virtual event hypotheses for predefined geographic regions. (S-1373; Common)
Requirements Trace: SRD-124, SRD-136, SRD-144

3.2.3.3.3.5 The System shall provide the Analyst the capability to view beam parameters. (S-1374; Common)
Requirements Trace: SRD-124, SRD-136, SRD-171

3.2.3.3.3.6 The System shall provide the Analyst the capability to select channels included in a beam from a subset of configured channels. (S-1375; Common)
Requirements Trace: SRD-124, SRD-136, SRD-384

3.2.3.3.3.7 The System shall provide the Analyst the capability to create beams for a user specified time interval. (S-1376; Common)
Requirements Trace: SRD-124, SRD-136, SRD-384

3.2.3.3.3.8 The System shall provide the Analyst the capability to create beams for a user specified azimuth and slowness selected from an fk spectra. (S-1377; Common)
Requirements Trace: SRD-124, SRD-136, SRD-145, SRD-384

3.2.3.3.3.9 The System shall provide the Analyst the capability to create beams for a user specified event hypothesis and phase. (S-1378; Common)
Requirements Trace: SRD-124, SRD-136, SRD-145, SRD-384

3.2.3.3.3.10 The System shall provide the Analyst the capability to create beams for a user specified hypocenter (latitude, longitude, depth) and phase. (S-1379; Common)
Requirements Trace: SRD-124, SRD-136, SRD-145, SRD-384

3.2.3.3.3.11 The System shall provide the Analyst the capability to form coherent beams. (S-1380; Common)
Requirements Trace: SRD-124, SRD-136, SRD-384

3.2.3.3.3.12 The System shall provide the Analyst the capability to form incoherent beams. (S-1381; Common)
Requirements Trace: SRD-124, SRD-136, SRD-384

3.2.3.3.3.13 The System shall provide the Analyst the capability to create beams for a user specified/selected point in slowness space. (S-1382; Common)
Requirements Trace: SRD-124, SRD-136, SRD-145

3.2.3.3.3.14 The System shall provide the Analyst the capability to view array coherence. (S-1383; Common)
Requirements Trace: SRD-124, SRD-136, SRD-245

3.2.3.3.4 Beamforming Storage

3.2.3.3.4.1 The System shall store the beam definition parameters for all beams. (S-1386; Common)
Requirements Trace: SRD-171, SRD-189, SRD-384

3.2.3.3.4.2 The System shall store continuous beams for virtual event hypotheses for predefined geographic regions. (S-1387; Common)
Requirements Trace: SRD-189

3.2.3.4 Derived Waveform Data

The System indefinitely stores raw waveforms and derived waveforms with associated signal detections. Once stored, derived waveforms with no associated signal detections will be deleted after the Operational Processing Time Period unless saved by the Analyst.

3.2.3.4.1 Derived Waveform Data Support Interfaces

3.2.3.4.1.1 The System shall provide the System Maintainer the capability to configure which derived waveforms with no related signal detections are stored during automated processing. (S-1391; Common)
Requirements Trace: SRD-180

3.2.3.4.2 Derived Waveform User Interfaces

3.2.3.4.2.1 The System shall provide the Analyst the capability to store selected derived waveforms. (S-2420; Common)
Requirements Trace: SRD-171, SRD-189

3.2.3.4.3 Derived Waveform Data Storage

3.2.3.4.3.1 The System shall store all derived channels related to one or more signal detections. (S-1393; Common)
Requirements Trace: SRD-171

3.2.3.4.3.2 The System shall store derived waveform data with no related signal detections for the Operational Processing Time Period. (S-1394; Common)
Requirements Trace: SRD-171, SRD-180

3.2.4 Signal Detection

The System is designed to automatically and continuously detect signals of interest.

A signal detection marks a signal of interest's onset time on a particular channel.

Power detectors are used to find signal onset by recognizing sudden increases in a waveform's energy content over the typical (background noise) energy content of the waveform. Power detectors work by forming a detection when the ratio of the waveform's short term average energy (STA) to the waveform's long term average energy (LTA) exceeds a threshold value. The phrases "short term" and "long term" are used to indicate relative lengths of time, and the LTA is assumed to represent the background noise level.

Z detectors are extensions of power detectors used to find signal onset by recognizing when STA differs from LTA by more than the amount expected for a time period containing only background noise. To do this, the standard error, Z, of (STA-LTA) is computed and detections are formed when the ratio of (STA-LTA) to Z exceeds a threshold.

Log-Z detectors operate the same as Z-detectors but use log(STA) and log(LTA) in place of STA and LTA.

Power detectors, Z detectors, and log-Z detectors are parameterized by: short term time length, long term time length, the offset between the beginning of the short term and long term time periods, and threshold.

F detectors are used by array stations to find signal onset time. The signal is assumed to be coherent across array elements and the noise is assumed to be incoherent, so the background noise power is estimated using the residuals between each array element's power and the beam power. Because of this, the time period used to find signal power is the same as the time period used to find the noise power. F detectors form a detection when the ratio of beam power to noise power exceeds a threshold.

F detectors are parameterized by: the time period used to calculate power and threshold.

Waveform correlation detectors find waveform sections containing high cross correlation with waveforms from known events. Waveform correlation detection includes subspace detection.

In addition to the parameters that control when detections are declared, detectors must also have parameters controlling the time intervals detectors must wait before declaring new signal detections. Too short an interval can lead to bursts of spurious detections following a legitimate

detection while too long an interval can lead to missing legitimate detections. Waiting time intervals only prevent signal detectors from declaring new signal detections for signals arriving with the same azimuth and slowness as the original signal detection initiating the time interval.

3.2.4.1 Signal Detection Processing

3.2.4.1.1 The System shall use power detectors to form signal detections on waveforms. (S-1397; Common)
Requirements Trace: SRD-448

3.2.4.1.2 The System shall use Z detectors to form signal detections on waveforms. (S-1398; Common)
Requirements Trace: SRD-448

3.2.4.1.3 The System shall use log-Z detectors to form signal detections on waveforms. (S-1399; Common)
Requirements Trace: SRD-448

3.2.4.1.4 The System shall use the Progressive Multi-Channel Correlation (PMCC) detector to form signal detections on waveforms. (S-5573; Common)
Requirements Trace: SRD-448

3.2.4.1.5 The System shall use F detectors to form signal detections on beams. (S-1400; Common)
Requirements Trace: SRD-448

3.2.4.1.6 The System shall detect signals of interest in waveform data by correlating the waveform with waveforms from historic event hypotheses. (S-1401; Common)
Requirements Trace: SRD-448

3.2.4.1.7 The System shall use array sensor waveforms to detect signals based on time periods containing spatially coherent data. (S-1402; Common)
Requirements Trace: SRD-448

3.2.4.1.8 The System shall use a statistical approach to address the loss of coherence between sensors when performing array signal detection. (S-5574; IDC only)
Requirements Trace: SRD-448

3.2.4.1.9 The System shall make separate signal detections for signals arriving at a station for simultaneous arrivals from different directions. (S-1406; Common)
Requirements Trace: SRD-55

3.2.4.1.10 The System shall identify microbarom signals. (S-5641; Common)
Requirements Trace: SRD-413

3.2.4.1.11 The System shall filter out detected microbarom signals. (S-5642; Common)
Requirements Trace: SRD-413

3.2.4.2 Signal Detection Support Interfaces

3.2.4.2.1 The System shall provide the System Maintainer the capability to configure signal detection parameters per channel. (S-1408; Common)
Requirements Trace: SRD-56, SRD-448

3.2.4.2.2 The System shall provide the System Maintainer the capability to configure channel detection criteria by time of year. (S-1409; Common)
Requirements Trace: SRD-54

3.2.4.2.3 The System shall provide the System Maintainer the capability to configure channel detection criteria by time of day. (S-1410; Common)
Requirements Trace: SRD-54

3.2.4.2.4 The System shall provide the System Maintainer the capability to configure signal processing operations to apply prior to signal detection. (S-1411; Common)
Requirements Trace: SRD-52

3.2.4.2.5 The System shall provide the System Maintainer the capability to configure signal processing operations to apply prior to signal detection by geographic region. (S-1412; Common)
Requirements Trace: SRD-52

3.2.4.2.6 The System shall provide the System Maintainer the capability to configure signal processing operations to apply prior to signal detection by station. (S-1413; Common)
Requirements Trace: SRD-52

3.2.4.2.7 The System shall provide the System Maintainer the capability to configure subspace waveform correlation signal detectors. (S-2348; Common)
Requirements Trace: SRD-448

3.2.4.2.8 The System shall provide the System Maintainer the capability to configure single channel waveform correlation signal detectors. (S-2349; Common)
Requirements Trace: SRD-448

3.2.4.2.9 The System shall provide the System Maintainer the capability to configure multi-component waveform correlation signal detectors. (S-2350; Common)
Requirements Trace: SRD-448

3.2.4.2.10 The System shall provide the System Maintainer the capability to configure array station waveform correlation signal detectors. (S-2351; Common)
Requirements Trace: SRD-448

3.2.4.2.11 The System shall provide the System Maintainer the capability to configure the microbarom identification parameters. (S-5643; Common)
Requirements Trace: SRD-413

3.2.4.3 Signal Detection User Interfaces

3.2.4.3.1 The System shall provide the Analyst the capability to add signal detections. (S-1416; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.4.3.2 The System shall provide the Analyst the capability to view Progressive Multi-Channel Correlation (PMCC) results. (S-5851; Common)
Requirements Trace: SRD-124, SRD-136

3.2.4.3.3 The System shall provide the Analyst the capability to reject signal detections. (S-1417; Common)
Requirements Trace: SRD-124, SRD-136

3.2.4.3.4 The System shall provide the Analyst the capability to modify the time of signal detections on the waveform display. (S-1418; Common)
Requirements Trace: SRD-124, SRD-136

3.2.4.3.5 The System shall provide the Analyst the capability to create signal detections when waveform data is not available. (S-1419; Common)
Requirements Trace: SRD-124, SRD-136

3.2.4.3.6 The System shall provide the Researcher the capability to create subspace waveform correlation signal detectors. (S-1414; Common)
Requirements Trace: SRD-448

3.2.4.3.7 The System shall provide the Researcher the capability to create single channel waveform correlation signal detectors. (S-2345; Common)
Requirements Trace: SRD-448

3.2.4.3.8 The System shall provide the Researcher the capability to create multi-component waveform correlation signal detectors. (S-2346; Common)
Requirements Trace: SRD-448

3.2.4.3.9 The System shall provide the Researcher the capability to create array station waveform correlation signal detectors. (S-2347; Common)
Requirements Trace: SRD-448

3.2.4.4 Signal Detection Storage

3.2.4.4.1 The System shall store all signal detections. (S-1421; Common)
Requirements Trace: SRD-189, SRD-448

3.2.5 Feature Extraction
Feature extraction is a range of time domain and frequency domain waveform processing to measure alphanumeric parameters from waveforms.

Feature extraction includes time domain waveform measurements, polarization feature measurements, frequency domain waveform measurements, and frequency-wavenumber measurements.

3.2.5.1 Time Domain Waveform Measurements

Time domain measurements are: period, peak-to-peak amplitude, zero-to-peak amplitude, signal to noise ratio, and RMS amplitude.

Additional hydroacoustic time domain measurements are: signal termination time, signal summation time, signal time spread, signal skewness, signal kurtosis, peak energy in a defined time period, intensity average time in a defined time period, peak energy in a defined time period, and crossing counts (the number of times a waveform crosses a threshold in a defined time period).

3.2.5.1.1 Time Domain Waveform Measurements Processing

3.2.5.1.1.1 The System shall compute time domain measurements for signal detections. (S-1425; Common)
Requirements Trace: SRD-62

3.2.5.1.1.2 The System software shall provide an extensible architecture for integrating new amplitude algorithms and measurements. (S-1426; Common)
Requirements Trace: SRD-66

3.2.5.1.1.3 The System shall compute infrasound closure and consistency measurements. (S-5630; Common)
Requirements Trace: SRD-62

3.2.5.1.1.4 The System shall compute uncertainties for observed signal detection measurements. (S-1427; Common)
Requirements Trace: SRD-102

3.2.5.1.2 Time Domain Waveform Measurements Support Interfaces

3.2.5.1.2.1 The System shall provide the System Maintainer the capability to configure time domain measurement configuration parameters per channel. (S-1429; Common)
Requirements Trace: SRD-56, SRD-62

3.2.5.1.2.2 The System shall provide the System Maintainer the capability to configure time domain measurement configuration parameters by geographic region. (S-1430; Common)
Requirements Trace: SRD-62

3.2.5.1.3 Time Domain Waveform Measurements User Interfaces

3.2.5.1.3.1 The System shall provide the Analyst the capability to view time domain measurements. (S-1432; Common)
Requirements Trace: SRD-62, SRD-124, SRD-136

3.2.5.1.3.2 The System shall provide the Analyst the capability to perform time domain waveform measurements. (S-1433; Common)
Requirements Trace: SRD-62, SRD-124, SRD-136

3.2.5.1.3.3 The System shall provide the Analyst the capability to select time domain waveform measurement parameters. (S-1434; Common)
Requirements Trace: SRD-124, SRD-136

3.2.5.1.3.4 The System shall provide the Analyst the capability to modify time domain waveform measurements. (S-1435; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.5.1.4 Time Domain Waveform Measurements Storage

3.2.5.1.4.1 The System shall store time domain measurements. (S-1438; Common)
Requirements Trace: SRD-62, SRD-189

3.2.5.2 Polarization Feature Measurements
The System measures polarization features for 3-component seismic stations.

Polarization feature measurements are: azimuth, azimuth uncertainty, rectilinearity, planarity, long axis incidence angle, short axis incidence angle, slowness, slowness uncertainty, the horizontal-to-vertical power ratio, and pseudo fk.

3.2.5.2.1 Polarization Feature Measurements Processing

3.2.5.2.1.1 The System shall compute polarization feature measurements. (S-1441; Common)
Requirements Trace: SRD-44, SRD-62

3.2.5.2.2 Polarization Feature Measurements Support Interfaces

3.2.5.2.2.1 The System shall provide the System Maintainer the capability to configure polarization feature measurement parameters per channel. (S-1443; Common)
Requirements Trace: SRD-44, SRD-56, SRD-62

3.2.5.2.3 Polarization Feature Measurements User Interfaces

3.2.5.2.3.1 The System shall provide the Analyst the capability to view polarization feature measurements. (S-1445; Common)
Requirements Trace: SRD-44, SRD-62, SRD-124, SRD-136, SRD-382

3.2.5.2.3.2 The System shall provide the Analyst the capability to make polarization feature measurements. (S-1446; Common)
Requirements Trace: SRD-44, SRD-62, SRD-124, SRD-136

3.2.5.2.3.3 The System shall provide the Analyst the capability to select polarization feature measurement parameters per channel. (S-1447; Common)
Requirements Trace: SRD-44, SRD-124, SRD-136

3.2.5.2.4 Polarization Feature Measurements Storage

3.2.5.2.4.1 The System shall store polarization feature measurements. (S-1450; Common)
Requirements Trace: SRD-44, SRD-62, SRD-189, SRD-382

3.2.5.3 Frequency Domain Waveform Measurements
Frequency domain waveform measurements are: total energy, total power, average power, power spectral density, and signal spectrum.

3.2.5.3.1 Frequency Domain Waveform Measurements Processing

3.2.5.3.1.1 The System shall compute frequency domain waveform measurements. (S-1453; Common)
Requirements Trace: SRD-41

3.2.5.3.1.2 The System shall compute the Fourier transform of a waveform. (S-1454; Common)
Requirements Trace: SRD-41

3.2.5.3.1.3 The System shall compute the inverse Fourier transform of a waveform. (S-1455; Common)
Requirements Trace: SRD-41

3.2.5.3.1.4 The System shall calculate spectrograms for any channel. (S-2101; Common)
Requirements Trace: SRD-124, SRD-136, SRD-264

3.2.5.3.1.5 The System shall calculate power spectral density. (S-2104; Common)
Requirements Trace: SRD-238

3.2.5.3.2 Frequency Domain Waveform Measurements Support Interfaces

3.2.5.3.2.1 The System shall provide the System Maintainer the capability to configure frequency domain waveform measurement parameters per channel. (S-1457; Common)
Requirements Trace: SRD-41, SRD-56

3.2.5.3.2.2 The System shall provide the System Maintainer the capability to configure frequency domain waveform measurement parameters by geographic region. (S-1458; Common)
Requirements Trace: SRD-41

3.2.5.3.2.3 The System shall provide the System Maintainer the capability to configure the parameters used to calculate spectrograms per channel. (S-5719; Common)
Requirements Trace: SRD-238, SRD-264

3.2.5.3.2.4 The System shall provide the System Maintainer the capability to configure the parameters used to calculate power spectral density for any channel. (S-5721; Common)
Requirements Trace: SRD-238

3.2.5.3.3 Frequency Domain Waveform Measurements User Interfaces

3.2.5.3.3.1 The System shall provide the Analyst the capability to make frequency domain waveform measurements. (S-1460; Common)
Requirements Trace: SRD-41, SRD-124, SRD-136

3.2.5.3.3.2 The System shall provide the Analyst the capability to view frequency domain waveform measurements. (S-1461; Common)
Requirements Trace: SRD-41, SRD-124, SRD-136

3.2.5.3.3.3 The System shall provide the Analyst the capability to select frequency domain waveform measurement parameters. (S-1462; Common)
Requirements Trace: SRD-41, SRD-124, SRD-136

3.2.5.3.3.4 The System shall provide the System User the capability to view spectrograms for any channel. (S-2099; Common)
Requirements Trace: SRD-124, SRD-136, SRD-238, SRD-264

3.2.5.3.3.5 The System shall provide the System User the capability to select the parameters used to calculate spectrograms per channel. (S-2100; Common)
Requirements Trace: SRD-124, SRD-136, SRD-238, SRD-264

3.2.5.3.3.6 The System shall provide the System User the capability to view power spectral density for any channel. (S-2102; Common)
Requirements Trace: SRD-124, SRD-136, SRD-238

3.2.5.3.3.7 The System shall provide the System User the capability to select the parameters used to calculate power spectral density for any channel. (S-2103; Common)
Requirements Trace: SRD-124, SRD-136, SRD-238

3.2.5.3.4 Frequency Domain Waveform Measurements Storage

3.2.5.3.4.1 The System shall store frequency domain waveform measurements. (S-1465; Common)
Requirements Trace: SRD-41, SRD-189

3.2.5.3.4.2 The System shall store spectrograms. (S-5720; Common)
Requirements Trace: SRD-189, SRD-238

3.2.5.3.4.3 The System shall store power spectral density. (S-5722; Common)
Requirements Trace: SRD-189, SRD-238

3.2.5.4 Frequency-Wavenumber (fk) Power Spectra Measurements
The System computes fk spectra from waveforms recorded by array station elements. The term "fk spectra" refers to fk power spectra and F-statistic, and is the term used in specifications that apply to both. If a specification applies to only the fk power spectra or the F-statistic, then either the term "fk power spectra" or "F-statistic" is used as needed.

The System takes feature measurements from the fk spectra.

The fk spectra measurements are: slowness, slowness uncertainty, azimuth, azimuth uncertainty, and array coherence.

3.2.5.4.1 Frequency-Wavenumber (fk) Power Spectra Measurements Processing

3.2.5.4.1.1 The System shall calculate fk spectra for a set of waveforms. (S-1468; Common)
Requirements Trace: SRD-42

3.2.5.4.1.2 The System shall make fk spectra measurements on fk spectra. (S-1469; Common)
Requirements Trace: SRD-42

3.2.5.4.1.3 The System shall normalize array station channels for fk spectra calculations. (S-1470; Common)
Requirements Trace: SRD-42

3.2.5.4.1.4 The System shall apply fk space-based filters to fk spectra. (S-1471; Common)
Requirements Trace: SRD-67

3.2.5.4.1.5 The System shall account for differences in array element sensor vertical position when calculating fk spectra. (S-2359; Common)
Requirements Trace: SRD-42

3.2.5.4.1.6 The System shall measure the azimuth and slowness and their uncertainties from fk spectra for each signal detection created for a primary seismic array station. (S-5786; IDC only)
Requirements Trace: SRD-446

3.2.5.4.2 Frequency-Wavenumber (fk) Spectra Measurements Support Interfaces

3.2.5.4.2.1 The System shall provide the System Maintainer the capability to configure fk spectra measurement parameters per channel. (S-1473; Common)
Requirements Trace: SRD-42, SRD-56, SRD-67

3.2.5.4.2.2 The System shall provide the System Maintainer the capability to configure fk spectra measurement parameters by phase type. (S-1474; Common)
Requirements Trace: SRD-42, SRD-67

3.2.5.4.2.3 The System shall provide the System Maintainer the capability to configure if array station waveform data is automatically normalized prior to fk spectra calculations. (S-1475; Common)
Requirements Trace: SRD-42

3.2.5.4.2.4 The System shall provide the System Maintainer the capability to configure fk space-based filters. (S-1476; Common)
Requirements Trace: SRD-67

3.2.5.4.3 Frequency-Wavenumber (fk) Spectra Measurements User Interfaces

3.2.5.4.3.1 The System shall provide the Analyst the capability to view normalized fk spectra plots for a selected set of waveforms. (S-1478; Common)
Requirements Trace: SRD-42, SRD-124, SRD-136

3.2.5.4.3.2 The System shall provide the Analyst the capability to view absolute fk spectra plots for a selected set of waveforms. (S-1479; Common)
Requirements Trace: SRD-42, SRD-124, SRD-136

3.2.5.4.3.3 The System shall provide the Analyst the capability to apply fk space based filters. (S-1480; Common)
Requirements Trace: SRD-67, SRD-124, SRD-136

3.2.5.4.3.4 The System shall provide the Analyst the capability to make fk spectra measurements on fk spectra. (S-1481; Common)
Requirements Trace: SRD-42, SRD-124, SRD-136

3.2.5.4.3.5 The System shall provide the Analyst the capability to select fk spectra measurement parameters. (S-1482; Common)
Requirements Trace: SRD-42, SRD-124, SRD-136

3.2.5.4.3.6 The System shall provide the Analyst the capability to normalize waveform data for an array prior to fk spectra calculations. (S-1483; Common)
Requirements Trace: SRD-42

3.2.5.4.4 Frequency-Wavenumber (fk) Spectra Measurements Storage

3.2.5.4.4.1 The System shall store fk spectra measurements. (S-1486; Common)
Requirements Trace: SRD-42, SRD-189

3.2.5.5 Seismic Station Signal Detection Phase Assignment

Initial seismic phase identifications are made for seismic signal detections prior to using the signal detections in network event hypothesis processing. The signal detections from a single seismic station are collected into signal detection groups believed to represent signal detections of the same event. Phase assignments are then made for each group of signal detections using measurements based on the actual signal detections and expected observations of the event hypothesis based on geophysical properties, empirical knowledge, and model based parameters.

Seismic signal detection phase assignment takes as input a collection of signal detections (and measurements based on those detections) from a single station and outputs the provided collection of signal detections with updated phase assignments.

Seismic signal detection phase assignment parameters are: channel waveform data, arrival time, amplitude, slowness, azimuth, horizontal-to-vertical power ratio, frequency, phases of other seismic signal detections in the group, data availability, and Signal QC measurements.

After grouping seismic signal detections into event hypotheses, residuals for the above parameters, empirical phase identification matching using the above parameters, empirical values

for the above parameters, the event hypothesis itself (e.g., magnitude, depth for depth phases), can also be used.

Seismic signal detection grouping criteria are combinations of: number of seismic signal detections, types of seismic signal detection phase assignments, number of seismic signal detection phase assignments of particular types, values of the seismic signal detection phase assignment parameters, thresholds for Signal Detection QC Metrics, and the method used to form groups and/or make phase identifications (e.g., waveform correlation might be weighted more heavily than classic techniques).

3.2.5.5.1 Seismic Station Signal Detection Phase Assignment Processing

3.2.5.5.1.1 The System shall group seismic signal detections from a single station that belong to the same event. (S-1489; Common)
Requirements Trace: SRD-75

3.2.5.5.1.2 The System shall use seismic signal detection phase assignment parameters and presumed event hypotheses formed using the seismic signal detection grouping criteria to assign phases to seismic signal detections. (S-1490; Common)
Requirements Trace: SRD-64, SRD-75, SRD-78

3.2.5.5.1.3 The System shall support concurrent seismic signal detection grouping criteria. (S-1491; Common)
Requirements Trace: SRD-64, SRD-75

3.2.5.5.1.4 The System shall use event location to assign phase identifications to signal detections based on predicted phase ID matching. (S-5600; Common)
Requirements Trace: SRD-74

3.2.5.5.1.5 The System shall use event location to assign phase identifications to signal detections based on available empirical phase ID matching. (S-5601; Common)
Requirements Trace: SRD-74

3.2.5.5.2 Seismic Station Signal Detection Phase Assignment Operational User Interfaces

3.2.5.5.2.1 The System shall provide the System Maintainer the capability to configure the seismic signal detection grouping criteria. (S-1493; Common)
Requirements Trace: SRD-64

3.2.5.5.2.2 The System shall provide the System Maintainer the capability to configure the seismic signal detection phase assignment parameters. (S-1494; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.5.2.3 The System shall provide the System Maintainer the capability to configure seismic signal detection grouping criteria by geographic region. (S-1495; Common)
Requirements Trace: SRD-64

3.2.5.5.2.4 The System shall provide the System Maintainer the capability to configure seismic signal detection grouping criteria by station. (S-1496; Common)
Requirements Trace: SRD-64, SRD-189

3.2.5.5.2.5 The System shall provide the System Maintainer the capability to configure seismic signal detection phase assignment parameters by station. (S-1497; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.5.2.6 The System shall provide the System Maintainer the capability to configure seismic signal detection phase assignment parameters by geographic region. (S-1498; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.5.3 Seismic Station Signal Detection Phase Assignment Support Interfaces

3.2.5.5.3.1 The System shall provide the System Maintainer the capability to configure the seismic signal detection grouping criteria by geographic region. (S-1523; Common)
Requirements Trace: SRD-76

3.2.5.6 Infrasonic Station Signal Detection Phase Assignment

3.2.5.6.1 Infrasonic Station Signal Detection Phase Assignment Processing

3.2.5.6.1.1 The System shall use infrasonic signal detection phase assignment parameters and presumed event hypotheses formed using the infrasonic signal detection grouping criteria to assign phases to infrasonic signal detections. (S-5647; Common)
Requirements Trace: SRD-64

3.2.5.6.1.2 The System shall group infrasonic signal detections from a single station that belong to the same event. (S-5633; Common)
Requirements Trace: SRD-75

3.2.5.6.1.3 The System shall support concurrent infrasound signal detection grouping criteria (S-5634; Common)
Requirements Trace: SRD-75

3.2.5.6.2 Infrasonic Station Signal Detection Phase Assignment Support Interfaces

3.2.5.6.2.1 The System shall provide the System Maintainer the capability to configure infrasonic phase grouping criteria. (S-5635; Common)
Requirements Trace: SRD-64, SRD-75

3.2.5.6.2.2 The System shall provide the System Maintainer the capability to configure infrasonic phase grouping criteria by station (S-5636; Common)
Requirements Trace: SRD-64, SRD-75

3.2.5.6.2.3 The System shall provide the System Maintainer the capability to configure the infrasound signal detection phase assignment parameters. (S-5639; Common)
Requirements Trace: SRD-76

3.2.5.6.2.4 The System shall provide the System Maintainer the capability to configure infrasound signal detection phase assignment parameters by station. (S-5640; Common)
Requirements Trace: SRD-76

3.2.5.6.3 Infrasonic Station Signal Detection Phase Assignment User Interfaces

3.2.5.6.3.1 The System shall provide the Analyst the capability to create infrasonic signal detection groups. (S-5637; Common)
Requirements Trace: SRD-64, SRD-75

3.2.5.6.3.2 The System shall provide the Analyst the capability to modify infrasonic signal detection groups. (S-5638; Common)
Requirements Trace: SRD-64, SRD-75

3.2.5.7 Hydroacoustic Signal Detection Groups (Hydroacoustic Arrival Groups)
A hydroacoustic signal detection group (also referred to as a hydroacoustic arrival group, or HAG) is a group of signal detections on different hydrophones from a single hydroacoustic station that have been determined to come from the same event and that can be used to determine azimuth back to the event. HAGs can only be formed for multiple element (array) stations, and hence apply to H stations but not T stations.

Hydroacoustic phase grouping criteria are: hydroacoustic signal detection feature measurements, group delay, types of signal detection phase assignments, number of signal detection phase assignments of particular types, thresholds for Signal Detection QC Metrics, and the method used to form signal detections and/or make phase identifications (e.g., waveform correlation might be weighted more heavily than other signal detection or event detection techniques).

3.2.5.7.1 Hydroacoustic Signal Detection Groups Processing

3.2.5.7.1.1 The System shall group hydroacoustic signal detections from a single station that belong to the same event (i.e. create hydroacoustic arrival groups). (S-2411; Common)
Requirements Trace: SRD-75

3.2.5.7.1.2 The System shall support concurrent hydroacoustic signal detections grouping criteria. (S-5626; Common)
Requirements Trace: SRD-75

3.2.5.7.1.3 The System shall use hydroacoustic signal detection phase assignment parameters and presumed event hypotheses formed using the hydroacoustic signal detection grouping criteria to assign phases to hydrocaoustic signal detections. (S-5644; Common)
Requirements Trace: SRD-64

3.2.5.7.2 Hydroacoustic Signal Detection Groups Support Interfaces

3.2.5.7.2.1 The System shall provide the System Maintainer the capability to configure hydroacoustic signal detection grouping criteria by geographic region. (S-2412; Common)
Requirements Trace: SRD-75

3.2.5.7.2.2 The System shall provide the System Maintainer the capability to configure hydroacoustic signal detection grouping criteria by station. (S-2413; Common)
Requirements Trace: SRD-75

3.2.5.7.2.3 The System shall provide the System Maintainer the capability to configure the hydroacoustic signal detection phase assignment parameters. (S-5627; Common)
Requirements Trace: SRD-76

3.2.5.7.2.4 The System shall provide the System Maintainer the capability to configure hydroacoustic signal detection phase assignment parameters by station. (S-5628; Common)
Requirements Trace: SRD-76

3.2.5.7.2.5 The System shall provide the System Maintainer the capability to configure hydroacoustic signal detection phase assignment parameters by geographic region. (S-5629; Common)
Requirements Trace: SRD-76

3.2.5.7.3 Hydroacoustic Signal Detection Groups User Interfaces

3.2.5.7.3.1 The System shall provide the Analyst the capability to select values for the hydroacoustic signal detection grouping criteria. (S-2414; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.7.3.2 The System shall provide the Analyst the capability to create hydroacoustic signal detection groups. (S-2415; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.7.3.3 The System shall provide the Analyst the capability to modify hydroacoustic signal detection groups. (S-2416; Common)
Requirements Trace: SRD-64, SRD-76

3.2.5.7.4 Hydroacoustic Signal Detection Groups Storage

3.2.5.7.4.1 The System shall store hydroacoustic signal detection groups (S-2417; Common)
Requirements Trace: SRD-189

3.2.6 Association
After signals are detected, they are associated to common event hypotheses.

3.2.6.1 Network Signal Association

Seismic, hydroacoustic, and infrasound signal detections are used to form event hypotheses and refine signal detection phase assignments in a process called network signal association. Event hypothesis formation criteria can be specified for creating single station event hypotheses, single

phenomenology event hypotheses, or multiple phenomenology event hypotheses. Network signal association takes as input a collection of signal detections (and measurements based on those detections) from a network of sensors. Network signal association outputs a collection of event hypotheses meeting the event hypothesis formation criteria and the input collection of signal detections with updated phase assignments.

Event hypotheses are defined by: location, time, magnitude, and associated signal detections.

Seismic network signal association parameters are: channel waveform data, arrival time, amplitude, slowness, azimuth, frequency, horizontal-to-vertical power ratio, rectilinearity, planarity, long axis incidence angle, short axis incidence angle, initial phase from seismic station signal detection phase assignment processing, data availability, Waveform QC measurements, Signal QC measurements, empirical phase identification matching using the above parameters, empirical values for the above parameters, and historic probability of signal detection for event hypotheses with similar locations and magnitudes.

After preliminary event hypothesis formation, residuals for the above parameters, the event hypothesis location itself (e.g., depth for depth phases), and the event hypothesis magnitude are also used.

Hydroacoustic network signal association parameters are: channel waveform data, arrival time, amplitude, azimuth, signal duration overlap, data availability, Waveform QC measurements, Signal QC measurements, empirical phase identification matching using the above parameters, empirical values for the above parameters, and historic probability of signal detection for event hypotheses with similar locations and magnitudes.

After preliminary event hypothesis formation, residuals for the above parameters, the event hypothesis location, path blockage, and event hypothesis magnitude are also used.

Infrasound network signal association parameters are: channel waveform data, arrival time, slowness, azimuth, data availability, Waveform QC measurements, Signal QC measurements, empirical phase identification matching using the above parameters, empirical values for the above parameters, and historic probability of signal detection for event hypotheses with similar locations and magnitudes.

Signal association event hypothesis formation criteria are: number of distinct stations with signal detections, types of stations with signal detections, number of signal detections, types of signal detection phase assignments, number of signal detection phase assignments of particular types, values of the network signal association parameters, thresholds for Signal Detection QC Metrics, the methods used to form event hypotheses and/or make phase identifications (e.g., waveform correlation might be weighted more heavily than classic techniques), and station quality metrics.

3.2.6.1.1 Network Signal Association Processing

3.2.6.1.1.1 The System shall use the seismic, hydroacoustic, and infrasound network signal association parameters to form event hypotheses from any combination of seismic, hydroacoustic, and infrasound signal detections meeting the signal association event

hypothesis formation criteria. (S-1504; Common)
Requirements Trace: SRD-73, SRD-76, SRD-77, SRD-78, SRD-79, SRD-89

3.2.6.1.1.2 The System shall use empirical values of the network signal association parameters during event hypothesis formation. (S-1505; Common)
Requirements Trace: SRD-79, SRD-99

3.2.6.1.1.3 The System shall use historic probability of signal detection during event hypothesis formation. (S-1506; Common)
Requirements Trace: SRD-79, SRD-99

3.2.6.1.1.4 The System shall use seismic network signal association parameters to assign phases to seismic signal detections. (S-1507; Common)
Requirements Trace: SRD-78

3.2.6.1.1.5 The System shall use hydroacoustic network signal association parameters to assign H phases to hydroacoustic signal detections at hydrophone stations. (S-1508; Common)
Requirements Trace: SRD-65, SRD-78

3.2.6.1.1.6 The System shall use hydroacoustic network signal association parameters to assign T phases to hydroacoustic signal detections from T-phase stations. (S-1509; Common)
Requirements Trace: SRD-65, SRD-78

3.2.6.1.1.7 The System shall use infrasound network signal association parameters to assign phases to infrasound signal detections. (S-1510; Common)
Requirements Trace: SRD-78, SRD-418

3.2.6.1.1.8 The System shall support concurrent signal association event hypothesis formation criteria. (S-1511; Common)
Requirements Trace: SRD-76, SRD-77

3.2.6.1.1.9 The System shall merge event hypotheses created using different event formation algorithms. (S-1512; Common)
Requirements Trace: SRD-77

3.2.6.1.1.10 The System shall associate unassociated signal detections created by any signal detection algorithm to event hypotheses formed by any event formation algorithm. (S-1513; Common)
Requirements Trace: SRD-77

3.2.6.1.1.11 The System shall compute the station probability of detecting an event hypothesis during event formation. (S-1514; Common)
Requirements Trace: SRD-72

3.2.6.1.1.12 The System shall use station-to-event distance when associating signal detections to events. (S-5596; Common)
Requirements Trace: SRD-72

3.2.6.1.1.13 The System shall use event magnitude when associating signal detections to events. (S-5597; Common)
Requirements Trace: SRD-72

3.2.6.1.1.14 The System shall use waveform data quality when associating signal detections to events. (S-5598; Common)
Requirements Trace: SRD-72

3.2.6.1.1.15 The System shall use station noise level when associating signal detections to events. (S-5599; Common)
Requirements Trace: SRD-72

3.2.6.1.1.16 The System shall use variable resolution representations of the Earth for signal association parameter predictions during signal association to account for the varying ability to resolve signals originating in different areas. (S-1515; Common)
Requirements Trace: SRD-84

3.2.6.1.1.17 The System shall create new event hypotheses which modify existing user-reviewed event hypotheses only when the event quality metric for the automatic event hypothesis improves more than a configured threshold. (S-1516; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.1.1.18 The System shall recreate previously rejected event hypotheses as a result of the Analyst invoking automated processing algorithms only when the event quality metric for the automatic event hypothesis improves more than a configured threshold. (S-1517; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.1.1.19 The System shall provide the Analyst the capability to recreate previously rejected event hypotheses as a result of invoking automated processing algorithms only when the event quality metric for the automatic event hypothesis improves more than a configured threshold. (S-2607; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.1.1.20 The System shall use the configured earth model(s) during signal detection association. (S-1518; Common)
Requirements Trace: SRD-71

3.2.6.1.1.21 The System shall build new events using signal detection templates. (S-3026; Common)
Requirements Trace: SRD-77

3.2.6.1.2 Network Signal Association Support Interfaces

3.2.6.1.2.1 The System shall provide the System Maintainer the capability to configure the signal association event hypothesis formation criteria. (S-1520; Common)
Requirements Trace: SRD-76, SRD-77, SRD-80

3.2.6.1.2.2 The System shall provide the System Maintainer the capability to configure the network signal association parameters by station. (S-1521; Common)
Requirements Trace: SRD-76, SRD-77, SRD-80

3.2.6.1.2.3 The System shall provide the System Maintainer the capability to configure the network signal association parameters by geographic region. (S-1522; Common)
Requirements Trace: SRD-76, SRD-77, SRD-80

3.2.6.1.2.4 The System shall provide the System Maintainer the capability to configure the signal association event hypothesis formation criteria by geographic region. (S-1524; Common)
Requirements Trace: SRD-76, SRD-77

3.2.6.1.2.5 The System shall provide the System Maintainer the capability to configure the signal association event hypothesis formation criteria for single station event hypotheses by station. (S-1525; Common)
Requirements Trace: SRD-64

3.2.6.1.2.6 The System shall provide the System Maintainer the capability to configure the event hypothesis merge criteria by geographic region. (S-1526; Common)
Requirements Trace: SRD-77

3.2.6.1.2.7 The System shall provide the System Maintainer the capability to configure the event quality metric improvement threshold for modifying user-reviewed event hypotheses. (S-1527; Common)
Requirements Trace: SRD-138

3.2.6.1.3 Network Signal Association User Interfaces

3.2.6.1.3.1 The System shall provide the Analyst the capability to associate signal detections to existing event hypotheses. (S-1529; Common)
Requirements Trace: SRD-124, SRD-136

3.2.6.1.3.2 The System shall provide the Analyst the capability to unassociate signal detections from existing event hypotheses. (S-1530; Common)
Requirements Trace: SRD-124, SRD-136

3.2.6.1.3.3 The System shall provide the Analyst the capability to assign phase labels to signal detections. (S-1531; Common)
Requirements Trace: SRD-124, SRD-136

3.2.6.1.3.4 The System shall provide the Analyst the capability to reject an event hypothesis. (S-1532; Common)
Requirements Trace: SRD-96, SRD-124, SRD-136

3.2.6.1.3.5 The System shall provide the Analyst the capability to invoke algorithms and parameters used during automated processing for the generation of new event hypotheses for evaluation. (S-1533; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.6.1.3.6 The System shall provide the Analyst the capability to select the signal association event hypothesis formation criteria. (S-1534; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.6.1.3.7 The System shall provide the Analyst the capability to invoke algorithms used during automated processing to find unassociated signal detections and associate them with existing event hypotheses. (S-1535; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.6.1.3.8 The System shall provide the Analyst the capability to form new event hypotheses from unassociated signal detections. (S-1536; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.1.3.9 The System shall provide the Analyst the capability to create a virtual event hypothesis (an event hypothesis with no associated signal detections). (S-1537; Common)
Requirements Trace: SRD-124, SRD-136

3.2.6.1.3.10 The System shall provide the Analyst the capability to define signal detection templates for automatic event hypothesis formation. (S-3023; Common)
Requirements Trace: SRD-124, SRD-136, SRD-142

3.2.6.1.3.11 The System shall provide the Analyst the capability to build events using a selected signal detection template. (S-3024; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.1.3.12 The System shall provide the Analyst the capability to create a signal detection template from an existing event. (S-3025; Common)
Requirements Trace: SRD-124, SRD-136, SRD-142

3.2.6.2 Late Network Signal Association

Late network signal association refers to network signal association for a time interval that is run after the initial network signal association for that time interval. It is triggered by the availability of signal detections for that time interval that were not available during the initial network signal association.

Late network signal association uses the network signal association parameters and signal association event hypothesis formation criteria used in network signal association. Late network signal association uses unassociated arrivals to form new event hypotheses and also associates arrivals to previously formed event hypotheses.

As part of event hypothesis formation, late network signal association compares potential event hypotheses to event hypotheses previously rejected during interactive review. If late network

signal association finds a potential event hypothesis matching a previously rejected event hypothesis, the event hypothesis is not reformed. Parameters used to prevent reforming rejected event hypotheses are: event location and tolerances on each event location parameter.

Late network signal association occurs as needed and may run zero or more times for a time interval.

3.2.6.2.1 Late Network Signal Association Processing

3.2.6.2.1.1 The System shall perform late network signal association using the seismic, hydroacoustic, and infrasound network signal association parameters to form event hypotheses from any combination of seismic, hydroacoustic, and infrasound signal detections meeting the signal association event hypothesis formation criteria. (S-1540; Common)
Requirements Trace: SRD-73, SRD-76, SRD-77, SRD-79, SRD-81, SRD-280, SRD-421

3.2.6.2.1.2 The System shall perform late network signal association for a time interval when one or more signal detections for that time interval become available that were not available during prior network signal association or late network signal associations for that time interval. (S-1541; Common)
Requirements Trace: SRD-79, SRD-81, SRD-217, SRD-280

3.2.6.2.1.3 The System shall not automatically perform network signal association affecting signal detections that the Analyst is actively reviewing. (S-1542; Common)
Requirements Trace: SRD-79, SRD-81

3.2.6.2.1.4 The System shall set signal detections to non-defining for event hypothesis location calculations when the System automatically associates them to Analyst reviewed event hypotheses. (S-1543; Common)
Requirements Trace: SRD-83

3.2.6.2.1.5 The System shall set station magnitudes to non-defining for event hypothesis magnitude calculations when the System automatically associates them to Analyst reviewed event hypotheses. (S-1544; Common)
Requirements Trace: SRD-83

3.2.6.2.1.6 The System shall recreate an event hypothesis during late association that was rejected in user review only when the event quality metric for the automatic event hypothesis improves more than a configured threshold or when the new event hypothesis definition differs from the original event hypothesis more than a configurable threshold. (S-1547; Common)
Requirements Trace: SRD-82

3.2.6.2.1.7 The System shall not automatically reassociate a signal detection to an event hypothesis if an Analyst has previously unassociated that signal detection from the event hypothesis. (S-1548; Common)
Requirements Trace: SRD-81, SRD-82, SRD-83

3.2.6.2.1.8 The System shall perform late network signal association during the operational processing time period. (S-1549; Common)
Requirements Trace: SRD-79, SRD-81, SRD-280

3.2.6.2.1.9 The System shall mark as requiring Analyst review any event previously reviewed by an Analyst that has its signal detection associations subsequently modified by the System. (S-2342; Common)
Requirements Trace: SRD-79, SRD-81

3.2.6.2.1.10 The System shall set to non-defining newly associated signal detections when the Analyst invokes automated processing algorithms to associate signal detections to existing event hypotheses. (S-1554; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.6.2.2 Late Network Signal Association Support Interfaces

3.2.6.2.2.1 The System shall provide the System Maintainer the capability to configure by geographic region the parameters used by late network signal association to prevent the formation of event hypotheses previously rejected during Analyst review. (S-1551; Common)
Requirements Trace: SRD-82

3.2.6.2.3 Late Network Signal Association User Interfaces

3.2.6.2.4 Late Network Signal Association Storage

3.2.6.2.4.1 The System shall store all event hypotheses formed by the System. (S-1556; Common)
Requirements Trace: SRD-79, SRD-82, SRD-138, SRD-189

3.2.6.2.4.2 The System shall store all signal detection associations for each event hypothesis stored by the System. (S-1557; Common)
Requirements Trace: SRD-189

3.2.6.3 Waveform Correlation
Waveform correlation event processors find event hypotheses in waveforms by searching databases of waveforms corresponding to historical event hypotheses. When a match is found there is high probability a new event hypothesis has occurred at nearly the same location as the original event hypothesis, allowing signal detections at stations across the network to be associated to the new event hypothesis by mapping them to compatible signal detections associated to the historical event hypothesis. Signal association and phase assignments based on waveform correlation event processing can occur for signal detections on any channel in the network, not just the channel correlated to the historical event hypothesis.

Compatible signal detections are found using the network signal association parameters.

3.2.6.3.1 Waveform Correlation Processing

3.2.6.3.1.1 The System shall associate signal detections to event hypotheses found with waveform correlation event processing by mapping signal detections on all network sensors to compatible signal detections on the historic waveforms. (S-1560; Common)
Requirements Trace: SRD-76, SRD-77, SRD-79

3.2.6.3.1.2 The System shall assign phase identifications to signal detections associated to event hypotheses found via waveform correlation to the same phases as the matching historic event hypotheses. (S-1561; Common)
Requirements Trace: SRD-64, SRD-78

3.2.6.3.1.3 The System shall locate event hypotheses found using waveform correlation processing using the same location algorithms as events found using other types of event processing. (S-1563; Common)
Requirements Trace: SRD-92

3.2.6.3.1.4 The System shall calculate signal detection feature measurement uncertainties for signal detections found using waveform correlation using the cross correlation coefficient. (S-1564; Common)
Requirements Trace: SRD-92

3.2.6.3.1.5 The System shall use waveform correlation to find historical event hypotheses occurring within a specified distance from an event hypothesis being analyzed. (S-2344; Common)
Requirements Trace: SRD-448

3.2.6.3.2 Waveform Correlation Support Interfaces

3.2.6.3.2.1 The System shall provide the System Maintainer the capability to configure the dynamic waveform correlation search parameters the System uses to find previously analyzed event hypotheses occurring at locations near an event hypothesis. (S-2352; Common)
Requirements Trace: SRD-448

3.2.6.3.2-1 Waveform Correlation User Interfaces

3.2.6.3.2-1.1 The System shall provide the Analyst the capability to select the dynamic waveform correlation search parameters the System uses to find previously analyzed event hypotheses occurring at locations near an event hypothesis. (S-2358; Common)
Requirements Trace: SRD-448

3.2.6.3.2.2 The System shall provide the System Maintainer the capability to configure the dynamic waveform correlation search parameters by geographic region. (S-2353; Common)
Requirements Trace: SRD-448

3.2.6.4 Conflict Resolution

Conflict resolution mediates automatically formed event hypotheses created by distinct network signal association processes. This might occur if separate network signal association processes are run for specific collections of stations or for event hypotheses occurring in specific areas. Conflict resolution:

1. Forces each signal detection to be associated to at most one event hypothesis.
2. Merges duplicate event hypotheses created by more than one association process into a single event hypothesis.
3. Corrects erroneously associated signal detections by moving signal detections between event hypotheses.

All event hypotheses formed or modified during conflict resolution meet the signal association event hypothesis formation criteria. If an event hypothesis modified during conflict resolution no longer meets the signal association event hypothesis formation criteria, the event hypothesis is dissolved by unassociating all of its signal detections.

Parameters used in conflict resolution are: the network signal association parameters and the signal association event hypothesis formation criteria.

3.2.6.4.1 Conflict Resolution Processing

3.2.6.4.1.1 The System shall use the seismic, hydroacoustic, and infrasound network signal association parameters and the signal association event hypothesis formation criteria to resolve situations where the same signal detection is associated to more than one event hypothesis by reassociating the signal detection to at most one event hypothesis. (S-1567; Common)
Requirements Trace: SRD-89, SRD-421

3.2.6.4.1.2 The System shall use the seismic, hydroacoustic, and infrasound network signal association parameters and the signal association event hypothesis formation criteria to merge redundant event hypotheses. (S-1568; Common)
Requirements Trace: SRD-89, SRD-421

3.2.6.4.1.3 The System shall use the seismic, hydroacoustic, and infrasound network signal association parameters and the signal association event hypothesis formation criteria to correct erroneously associated signal detections. (S-1569; Common)
Requirements Trace: SRD-89, SRD-421

3.2.6.5 Station Quality Metric

The station quality metric for an event hypothesis is represented as a real value in the closed interval [0.0, 1.0]. It is computed using a combination of the station network signal association parameters as well as: station type (array vs. non-array), and whether or not the station was operational during the time period it would observe the event (used to evaluate the significance of non-detecting stations).

3.2.6.5.1 Station Quality Metric Processing

3.2.6.5.1.1 The System shall compute the station quality metric for all stations for each event hypothesis. (S-1572; Common)
Requirements Trace: SRD-85, SRD-89, SRD-408

3.2.6.5.2 Station Quality Metric Operational Support Interfaces

3.2.6.5.2.1 The System shall provide the System User the capability to view station quality metrics. (S-1574; Common)
Requirements Trace: SRD-89

3.2.6.5.3 Station Quality Metric Storage

3.2.6.5.3.1 The System shall store the station quality metrics for all stations for each event hypothesis. (S-1576; Common)
Requirements Trace: SRD-89, SRD-189, SRD-408

3.2.6.6 Event Hypothesis Quality Metric

An event hypothesis quality metric indicating the quality of the event hypothesis is computed for every event hypothesis formed on the System. Event hypothesis quality metrics are represented as numbers between zero and one. The System forms event hypothesis quality metrics using event hypothesis quality statistics. The System recomputes event hypothesis quality metrics whenever any event hypothesis statistic is updated and stored. Event hypothesis quality metrics are calculated for automatic and Analyst created event hypotheses. Any automatic screening or decisions based on the event hypothesis quality metric is ignored for Analyst created or updated event hypotheses.

Event hypothesis quality statistics are: event hypothesis location uncertainty, number of station detections associated to the event hypothesis, signal detection quality statistics for signal detections associated to the event hypothesis, STA/LTA noise levels, SNR, location, travel-time residuals, azimuth residuals, slowness residuals, amplitude residuals, observed and non-observed maximum likely signal detection associations to the event hypothesis, similar historic event hypotheses and their associated signal detections.

3.2.6.6.1 Event Hypothesis Quality Metric Processing

3.2.6.6.1.1 The System shall compute an event hypothesis quality metric using the event hypothesis quality statistics for each event hypothesis formed on the System. (S-1579; Common)
Requirements Trace: SRD-85, SRD-88

3.2.6.6.1.2 The System shall recompute the event hypothesis quality metric for an event hypothesis when any of the event hypothesis quality statistics used to calculate the event hypothesis quality metric are updated. (S-1580; Common)
Requirements Trace: SRD-85, SRD-87, SRD-88

3.2.6.6.1.3 The System shall not automatically form event hypotheses with event hypothesis quality metrics below the event hypothesis quality metric threshold. (S-1581; Common)
Requirements Trace: SRD-86

3.2.6.6.1.4 The System shall not screen any Analyst created event hypotheses by their event hypothesis quality metrics. (S-1582; Common)
Requirements Trace: SRD-86

3.2.6.6.2 Event Hypothesis Quality Metric Support Interfaces

3.2.6.6.2.1 The System shall provide the System Maintainer the capability to configure the event hypothesis quality metric threshold by geographic region. (S-1584; Common)
Requirements Trace: SRD-86

3.2.6.6.2.2 The System shall provide the System Maintainer the capability to configure the event hypothesis quality metric threshold. (S-5620; Common)
Requirements Trace: SRD-86

3.2.6.6.3 Event Hypothesis Quality Metric User Interfaces

3.2.6.6.3.1 The System shall provide the Analyst the capability to view event hypothesis quality metrics. (S-1586; Common)
Requirements Trace: SRD-85, SRD-88, SRD-124, SRD-136

3.2.6.6.4 Event Hypothesis Quality Metric Storage

3.2.6.6.4.1 The System shall store the event hypothesis quality metric for each event hypothesis. (S-1588; Common)
Requirements Trace: SRD-85, SRD-189

3.2.6.7 Event Consistency

3.2.6.7.1 Event Consistency Processing

3.2.6.7.1.1 The System shall correct event parameters based on the Event Consistency Report as permitted by the configured settings. (S-5735; IDC only)
Requirements Trace: SRD-427

3.2.6.7.1.2 The System shall compute Event Consistency checks when an event hypothesis is saved. (S-5795; IDC only)
Requirements Trace: SRD-490

3.2.6.7.1.3 The System shall generate an Event Consistency check report in less than 3 seconds per event hypothesis. (S-5796; IDC only)
Requirements Trace: SRD-425

3.2.6.7.1.4 The System shall include a check of minimum number of primary stations as part of the event consistency calculation. (S-5815; IDC only)
Requirements Trace: SRD-424, SRD-624

3.2.6.7.1.5 The System shall include a check of sum of weights for associated arrivals as part of the event consistency calculation. (S-5816; IDC only)
Requirements Trace: SRD-424, SRD-624

3.2.6.7.1.6 The System shall perform an event consistency check that deep events have more than a specified threshold number of location defining signal detections. (S-5841; IDC only)
Requirements Trace: SRD-624

3.2.6.7.1.7 The System shall perform an event consistency check that valid event-related information is stored in the database. (S-5817; IDC only)
Requirements Trace: SRD-424, SRD-625

3.2.6.7.1.8 The System shall perform an event consistency check that the ordered list of phases at each station is consistent with the configured list of phases for the event location and magnitude. (S-5819; IDC only)
Requirements Trace: SRD-424, SRD-626

3.2.6.7.1.9 The System shall perform an event consistency check that there are no duplicate phases among the associated signal detections at each station. (S-5843; IDC only)
Requirements Trace: SRD-626

3.2.6.7.1.10 The System shall perform an event consistency check that there are no isolated secondary phases for the associated signal detections at each station. (S-5844; IDC only)
Requirements Trace: SRD-626

3.2.6.7.1.11 The System shall perform an event consistency check that the difference between ML and mb magnitudes is not larger than a specified threshold. (S-5820; IDC only)
Requirements Trace: SRD-424, SRD-626

3.2.6.7.1.12 The System shall include a check of observing stations related to event geographic location and magnitude as part of the event consistency calculation. (S-5823; IDC only)
Requirements Trace: SRD-424, SRD-626

3.2.6.7.1.13 The System shall include a check for station magnitude outliers as part of the event consistency calculation. (S-5824; IDC only)
Requirements Trace: SRD-424, SRD-626

3.2.6.7.1.14 The System shall include a check for consistency of time, azimuth, slowness defining settings per associated arrival as part of the event consistency calculation. (S-5825; IDC only)
Requirements Trace: SRD-424, SRD-627

3.2.6.7.1.15 The System shall perform an event consistency check that the time, azimuth, and slowness residuals for location defining associated signal detections do not exceed the configured thresholds. (S-5826; IDC only)
Requirements Trace: SRD-424, SRD-627

3.2.6.7.1.16 The System shall perform an event consistency check that a deep event is located in an area where deep events are known to occur. (S-5846; IDC only)
Requirements Trace: SRD-626

3.2.6.7.1.17 The System shall perform an event consistency check that if any signal detections belonging to a group of hydroacoustic signal detections is associated to an event, then all signal detections in the group must be associated. (S-5847; IDC only)
Requirements Trace: SRD-626

3.2.6.7.1.18 The System shall perform an event consistency check that the time, azimuth, and slowness residuals for location non-defining associated signal detections do not exceed the configured thresholds. (S-5849; IDC only)
Requirements Trace: SRD-627

3.2.6.7.2 Event Consistency Support Interfaces

3.2.6.7.2.1 The System shall provide the System Maintainer the capability to configure the event parameters that can be automatically corrected by the System. (S-5734; IDC only)
Requirements Trace: SRD-427

3.2.6.7.2.2 The System shall provide the System Maintainer the capability to configure the threshold number of location defining signal detections for deep events as part of the event consistency calculation. (S-5842; IDC only)
Requirements Trace: SRD-624

3.2.6.7.2.3 The System shall provide the System Maintainer the capability to configure the minimum number of event location defining primary stations as part of the event consistency calculation. (S-5833; IDC only)
Requirements Trace: SRD-624

3.2.6.7.2.4 The System shall provide the System Maintainer the capability to configure a threshold value of the sum of weights for location defining signal detections as part of the event consistency calculation. (S-5834; IDC only)
Requirements Trace: SRD-624

3.2.6.7.2.5 The System shall provide the System Maintainer the capability to configure an expected list of phases at each station as a function of event location and magnitude as part of the event consistency calculation. (S-5835; IDC only)
Requirements Trace: SRD-626

3.2.6.7.2.6 The System shall provide the System Maintainer the capability to configure a threshold values of the difference between ML and mb magnitudes as part of the event

consistency calculation. (S-5845; IDC only)
Requirements Trace: SRD-626

3.2.6.7.2.7 The System shall provide the System Maintainer the capability to configure an expected set of observing stations as a function of event location and magnitude as part of the event consistency calculation. (S-5836; IDC only)
Requirements Trace: SRD-626

3.2.6.7.2.8 The System shall provide the System Maintainer the capability to configure the station magnitude consistency with network magnitude range. (S-5837; IDC only)
Requirements Trace: SRD-626

3.2.6.7.2.9 The System shall provide the System Maintainer the capability to configure allowed values for time, azimuth, slowness defining settings per associated signal detection as part of the event consistency calculation. (S-5838; IDC only)
Requirements Trace: SRD-627

3.2.6.7.2.10 The System shall provide the System Maintainer the capability to configure the threshold value for time, azimuth, and slowness residuals for location defining associated signal detections as part of the event consistency calculation. (S-5839; IDC only)
Requirements Trace: SRD-627

3.2.6.7.2.11 The System shall provide the System Maintainer the capability to configure what geographic regions are known to have deep seismicity as part of the event consistency calculation. (S-5848; IDC only)
Requirements Trace: SRD-626

3.2.6.7.2.12 The System shall provide the System Maintainer the capability to configure the threshold value for time, azimuth, and slowness residuals for location non-defining associated signal detections as part of the event consistency calculation. (S-5850; IDC only)
Requirements Trace: SRD-627

3.2.6.7.3 Event Consistency User Interfaces

3.2.6.7.3.1 The System shall provide the Analyst the capability to interactively compute a subset of the Event Consistency checks. (S-5794; IDC only)
Requirements Trace: SRD-424, SRD-491

3.2.7 Location

Due to the heterogeneity of the Earth, location of events in three dimensions is a scientifically challenging problem. The System must integrate the constantly evolving state-of-the-art earth models and location algorithms.

3.2.7.1 Event Hypothesis Relocation

Event hypothesis relocation refers to a process used to determine an event's hypocenter and origin time using event hypothesis observations (and measurements from those observations) as recorded at one or more stations and either an Earth model or empirical observations of well-

located event hypotheses. Location algorithms have the goal of spatially and temporally locating an event hypothesis such that the actual event hypothesis observations align as closely as possible with expected observations of the event hypothesis made using either the Earth model or empirical data. Computed event hypothesis locations are estimates represented by spatial location, temporal location, and associated uncertainties.

Values used during event hypothesis location are:

- Signal detection measurements including uncertainties: arrival time, backazimuth, and horizontal slowness for signal detections associated to the event hypothesis.
- Signal Predictions including uncertainties: arrival time, backazimuth, horizontal slowness. Note: Predictions come from either empirical data or an Earth model.
- Preliminary event hypothesis location

Event hypothesis relocation parameters refer to the inputs to the relocation calculation: signal detection measurements and uncertainties, signal detection phase assignments, model predictions of the measurements, uncertainties of the model predictions, and a preliminary event hypothesis location.

Event hypothesis relocation components refer to the outputs of the relocation calculation: the hypocenter (latitude, longitude, and depth) and origin time of the event hypothesis, and the event hypothesis location uncertainty (the covariance matrix and the location uncertainty bound scaling factors).

N-location solutions: multiple different location solutions can be computed using the observations of any given event hypothesis by limiting the location solution's input parameters.

Individual signal detection measurements are either defining or non-defining for each event hypothesis relocation calculation. Each calculation only uses the defining signal detection measurements for that calculation.

The System uses two approaches to toggle signal detection measurements between defining and non-defining for event hypothesis location processing during event hypothesis relocation processing. First, signal detection measurements are made non-defining if their residuals from signal predictions (or residuals weighted by the signal detection measurement uncertainty) exceed a configurable threshold. Second, signal detection measurements are made non-defining if the System determines they are inconsistent with geophysical properties (e.g., a signal detection has a phase assignment that is impossible for the event hypothesis, such as a Pn signal detection at a teleseismic distance). The System toggles signal detections measurements it previously made non-defining for event location processing during event hypothesis relocation processing back to defining if the processing updates the event hypothesis location such that the signal detection measurement no longer meets the criteria used to make it non-defining.

The System uses these parameters to set criteria for toggling the signal detection defining/non-defining state: signal detection measurements, signal detection measurement uncertainties, signal predictions, signal prediction uncertainties, and signal detection phase assignments.

Event hypothesis location uncertainty is a general term referring to the values constraining an event hypothesis' estimated location at a given probability level. The most general uncertainty representation is the covariance matrix. This matrix can be used to build a 4-dimensional hyper-ellipse bounding an event hypothesis location's hypocenter and origin time. Projecting this hyper-ellipse onto other spaces yields other uncertainty bounds. Definitions for these other uncertainty bounds as used in the System are:

- Depth uncertainty: 1-dimensional uncertainty of the event hypothesis' depth. This value comes directly from the corresponding diagonal element of the covariance matrix.
- Time uncertainty: 1-dimensional uncertainty of the event hypothesis' temporal location. This value comes directly from the corresponding diagonal element of the covariance matrix.
- Uncertainty ellipse: 2-dimensional ellipse defining the joint uncertainty of the latitude and longitude of the event hypothesis. An ellipse is created by projecting the 4-dimensional hyper-ellipse onto the latitude-longitude plane.
- Uncertainty ellipsoid: 3-dimensional ellipsoid defining the joint uncertainty of the 3 components of the event hypothesis' hypocenter. An ellipsoid is created by projecting the 4-dimensional hyper-ellipse onto the three spatial dimensions.

Different types of event hypothesis location uncertainty bounds can be constructed though scaling. In each case, the basic shape and magnitudes of the uncertainty bounds are controlled by the uncertainties of the observations and model predictions propagated through the event hypothesis relocation calculation. Each of the different types of event hypothesis location uncertainty bounds involves a scale factor that adjusts the size of the uncertainty bounds to account for potential inaccuracy of the observation and model prediction uncertainties used in the relocation.

The available types of location uncertainty bound scaling factors are:

- Coverage bound scaling factor: location uncertainty bounds are scaled using an a priori estimate of the scale factor. The factor is set to 1 if the observation and model prediction uncertainties are believed to be correct but may be specified to be larger or smaller depending on if historical, empirical, information indicates that the uncertainties are too large or small, respectively.
- Confidence bound scaling factor: location uncertainty bounds are scaled using a posteriori information obtained by assuming that the weighted residuals after relocating the event hypothesis provide a reliable estimate of how accurate the original estimates of the observation and prediction uncertainties were. The scale factor is set equal to the mean sum squared weighted residual of all observations contributing to the location. For event hypothesis locations computed with a large number of observations, this value should be ~1 if the original estimates of the observation and prediction uncertainties were accurate.
- K-weighted bound scaling factor: location uncertainty bounds scaled using a weighted combination of the a priori and a posteriori scale factors.

3.2.7.1.1 Event Hypothesis Relocation Processing

3.2.7.1.1.1 The System shall compute event hypothesis relocations using any combination of the seismic, hydroacoustic, and infrasound event hypothesis relocation parameters. (S-1592; Common)
Requirements Trace: SRD-92, SRD-102, SRD-418, SRD-419

3.2.7.1.1.2 The System shall compute event hypothesis relocations using any combination of the event hypothesis relocation parameters from a single station. (S-1593; Common)
Requirements Trace: SRD-101

3.2.7.1.1.3 The System shall compute event hypothesis relocations using any combination of the event hypothesis relocation parameters from multiple stations. (S-1594; Common)
Requirements Trace: SRD-101

3.2.7.1.1.4 The System shall compute event hypothesis relocation uncertainty bounds from event hypothesis location covariance matrices and event hypothesis location uncertainty bound scaling factors. (S-1595; Common)
Requirements Trace: SRD-92

3.2.7.1.1.5 The System shall compute the uncertainty coverage ellipse for each event hypothesis relocation. (S-1596; Common)
Requirements Trace: SRD-92

3.2.7.1.1.6 The System shall compute new event hypothesis relocations when an automatic process associates a new location defining signal detection to that event hypothesis. (S-1597; Common)
Requirements Trace: SRD-100

3.2.7.1.1.7 The System shall compute new event hypothesis relocations when an automatic process unassociates a location defining signal detection from that event hypothesis. (S-1598; Common)
Requirements Trace: SRD-100

3.2.7.1.1.8 The System shall compute a new event hypothesis relocation when an automatic process modifies any event hypothesis relocation parameter contributing to that event hypothesis' location. (S-1599; Common)
Requirements Trace: SRD-100

3.2.7.1.1.9 The System shall set the defining/non-defining state for signal detection measurements during event hypothesis relocation processing. (S-1600; Common)
Requirements Trace: SRD-92

3.2.7.1.1.10 The System shall compute event hypothesis relocations using teleseismic and regional seismic signal detections. (S-1631; Common)
Requirements Trace: SRD-93

3.2.7.1.1.11 The System shall compute modeling uncertainties for model based predictions of signal detection measurements. (S-1601; Common)
Requirements Trace: SRD-102

3.2.7.1.2 Event Hypothesis Relocation Support Interfaces

3.2.7.1.2.1 The System shall provide the System Maintainer the capability to configure the criteria used during event hypothesis relocation processing to set the defining/non-defining state for signal detection measurements for event hypothesis relocation by geographic region. (S-1603; Common)
Requirements Trace: SRD-92, SRD-103

3.2.7.1.2.2 The System shall provide the System Maintainer the capability to configure the criteria used during event hypothesis relocation processing to set the defining/non-defining state for signal detection measurements for event hypothesis relocation by channel. (S-1604; Common)
Requirements Trace: SRD-92, SRD-103

3.2.7.1.3 Event Hypothesis Relocation User Interfaces

3.2.7.1.3.1 The System shall provide the Analyst the capability to set uncertainties for observed signal detection measurements. (S-1606; Common)
Requirements Trace: SRD-102, SRD-124, SRD-136

3.2.7.1.3.2 The System shall provide the Analyst the capability to select the confidence level used to compute an event hypothesis location uncertainty bound. (S-1607; Common)
Requirements Trace: SRD-92, SRD-124, SRD-136

3.2.7.1.3.3 The System shall provide the Analyst the capability to select the type of each event hypothesis location uncertainty bound to compute. (S-1608; Common)
Requirements Trace: SRD-92, SRD-124, SRD-136

3.2.7.1.3.4 The System shall provide the Analyst the capability to recompute an event hypothesis' location solutions. (S-1609; Common)
Requirements Trace: SRD-100, SRD-124, SRD-136

3.2.7.1.3.5 The System shall provide the Analyst the capability to select the defining/non-defining state for a signal detection time measurement for event hypothesis relocation unless prohibited by the default defining/non-defining state. (S-1610; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.7.1.3.6 The System shall provide the Analyst the capability to select the defining/non-defining state for a signal detection azimuth measurement for event hypothesis relocation unless prohibited by the default defining/non-defining state. (S-1611; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.7.1.3.7 The System shall provide the Analyst the capability to select the defining/non-defining state for a signal detection slowness measurement for event hypothesis relocation unless prohibited by the default defining/non-defining state. (S-1612; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.7.1.3.8 The System shall provide the Analyst the capability to select the defining/non-defining state for signal detection measurements for event hypothesis relocation based on channel unless prohibited by the default defining/non-defining state. (S-1613; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.7.1.3.9 The System shall provide the Analyst the capability to select the defining/non-defining state for signal detection measurements for event hypothesis relocation based on signal detection phase assignment unless prohibited by the default defining/non-defining state. (S-1614; Common)
Requirements Trace: SRD-103, SRD-124, SRD-136

3.2.7.1.4 Event Hypothesis Relocation Storage

3.2.7.1.4.1 The System shall store up to 300 unique event hypotheses for each event. (S-1618; Common)
Requirements Trace: SRD-94

3.2.7.1.4.2 The System shall store the confidence level of each computed event hypothesis location uncertainty bound. (S-1619; Common)
Requirements Trace: SRD-92, SRD-189

3.2.7.1.4.3 The System shall store the type (i.e., confidence, coverage, or k-weighted with the associated weights) of each location uncertainty bound. (S-1620; Common)
Requirements Trace: SRD-92, SRD-189

3.2.7.1.4.4 The System shall store modeling uncertainties for model based predictions of signal detection measurements. (S-1621; Common)
Requirements Trace: SRD-102, SRD-189

3.2.7.1.4.5 The System shall store uncertainties for observed signal detection measurements. (S-1622; Common)
Requirements Trace: SRD-102, SRD-189

3.2.7.1.4.6 The System shall store the sum squared weighted residual for each event hypothesis location. (S-1623; Common)
Requirements Trace: SRD-94, SRD-189

3.2.7.1.4.7 The System shall store the defining/non-defining state for each signal detection measurement associated to a stored event hypothesis. (S-1624; Common)
Requirements Trace: SRD-170, SRD-189

3.2.7.2 Restrained Event Hypothesis Relocation
Restrained event hypothesis locations limit one or more of the computed event hypothesis location components, the stations used to locate the event hypothesis, or the phases used to locate the event hypothesis. Unrestrained event hypothesis locations do not limit these parameters.

Restrainable event hypothesis location parameters are: latitude, longitude, depth, time, stations, and phases.

3.2.7.2.1 Restrained Event Hypothesis Relocation Support Interfaces

3.2.7.2.1.1 The System shall provide the System Maintainer the capability to configure which types of event hypothesis locations (e.g. restrained event hypothesis locations, unrestrained event hypothesis locations, types of n-locations) to automatically compute for each event hypothesis. (S-1633; Common)
Requirements Trace: SRD-94

3.2.7.2.1.2 The System shall provide the System Maintainer the capability to configure which types of event hypothesis locations to automatically compute by geographic region. (S-1634; Common)
Requirements Trace: SRD-94

3.2.7.2.2 Restrained Event Hypothesis Relocation User Interfaces

3.2.7.2.2.1 The System shall provide the Analyst the capability to compute restrained event hypothesis locations. (S-1636; Common)
Requirements Trace: SRD-94, SRD-124, SRD-136

3.2.7.2.2.2 The System shall provide the Analyst the capability to compute unrestrained event hypothesis locations. (S-1637; Common)
Requirements Trace: SRD-94, SRD-124, SRD-136

3.2.7.3 Relative Event Hypothesis Relocation

Relative event hypothesis relocation is an event hypothesis relocation process that simultaneously relocates a group of event hypotheses rather than relocating each event hypothesis individually. This allows the locator to take advantage of additional information based on the relative differences in measurements between event hypotheses.

Travel time differences between groups of event hypotheses can be calculated using: waveform cross correlation time offsets or signal detection onset times.

3.2.7.3.1 Relative Event Hypothesis Relocation Processing

3.2.7.3.1.1 The System shall perform master event relocation using travel time differences. (S-1640; Common)
Requirements Trace: SRD-92, SRD-129

3.2.7.3.2 Relative Event Hypothesis Relocation User Interfaces

3.2.7.3.2.1 The System shall provide the Researcher the capability to compute the relative relocations of a selected set of event hypotheses using a selected set of stations. (S-1642; Common)
Requirements Trace: SRD-124, SRD-129, SRD-136

3.2.7.3.2.2 The System shall provide the Analyst the capability to map signal detections and their phase assignments from one channel to another channel. (S-1643; Common)
Requirements Trace: SRD-124, SRD-129, SRD-136

3.2.7.3.2.3 The System shall provide the Analyst the capability to manually align waveforms. (S-1644; Common)
Requirements Trace: SRD-124, SRD-129, SRD-136

3.2.7.3.2.4 The System shall provide the Analyst the capability to align waveforms based on travel time differences. (S-1645; Common)
Requirements Trace: SRD-124, SRD-129, SRD-136

3.2.7.3.2.5 The System shall provide the Analyst the capability to align waveforms based on optimal lag calculated by waveform cross correlation. (S-1646; Common)
Requirements Trace: SRD-124, SRD-129, SRD-136

3.2.8 Source Properties

Source property calculations estimate the source sizes of event hypotheses using event hypothesis magnitude estimates. The System also computes moment tensor solutions for event hypotheses meeting certain criteria.

3.2.8.1 Magnitude Estimation

An event magnitude is a measure of the size of an event. An event magnitude measured from an event hypothesis is an estimate of the actual event's magnitude and is referred to as an event hypothesis magnitude estimate. Event hypothesis magnitude estimates are made using signal detection measurements, event hypothesis locations, and knowledge of Earth structure. Different types of magnitude estimates are made using different input parameters. For example, different types of magnitude estimates are made using the amplitudes of body waves and surface waves.

Event hypothesis magnitude estimate calculations are typically defined using linear relationships of their input parameters. Changing the constant coefficients used in a relationship produces a different type of event hypothesis magnitude estimate that is related to the original event hypothesis magnitude estimate. The general form of an event hypothesis magnitude estimate relationship can therefore be thought of as defining a family of related event hypothesis magnitude estimates, with different coefficient assignments used for different event hypothesis source types, locations, or source conditions.

Event hypothesis magnitude estimate calculation parameters are: magnitude type, signal amplitude, frequency band, event hypothesis location, signal decay (path, phase and frequency dependent), waveform data (for coda measurements), and a parameterization of the magnitude estimate function’s coefficients.

Relative event hypothesis magnitude estimate calculations use the magnitude estimate calculation parameters from multiple event hypotheses located in the same region to simultaneously estimate the magnitudes of each of the event hypotheses.

Maximum Likelihood Estimation (MLE) magnitudes for an event hypothesis use as input: the magnitude estimate calculation inputs for stations detecting the event hypothesis, magnitude estimate calculation inputs for stations not detecting the event hypothesis (measurements at non-detecting stations are for noise data at the expected signal arrival time rather than for signal detections), and empirical station detection thresholds.

Magnitude estimate calculations are: ML, mb, mbMLE, MS, MSMLE, MSVMAX, and Mwcoda.

Single station magnitude estimates are computed using the magnitude estimate calculation parameters from a single station. Network magnitude estimates are computed using two or more of the single station magnitude estimates for an event hypothesis and a parameterization of the combining function used to calculate the network magnitude estimate from the single station magnitude estimates. The values in the combining function's parameterization are dependent on the network magnitude estimate type.

3.2.8.1.1 Magnitude Estimation Processing

3.2.8.1.1.1 The System shall compute single station magnitude estimates using the station's event hypothesis magnitude estimate calculation parameters. (S-1650; Common)
Requirements Trace: SRD-106, SRD-107

3.2.8.1.1.2 The System shall compute network magnitude estimates using single station magnitude estimates and the network magnitude estimate combining function's parameter values. (S-1651; Common)
Requirements Trace: SRD-106

3.2.8.1.1.3 The System shall compute uncertainties for all event hypothesis magnitude estimates. (S-1652; Common)
Requirements Trace: SRD-108

3.2.8.1.1.4 The System shall compute new event hypothesis magnitude estimates when a new event hypothesis location is computed. (S-1653; Common)
Requirements Trace: SRD-106

3.2.8.1.2 Magnitude Estimation Support Interfaces

3.2.8.1.2.1 The System shall provide the System Maintainer the capability to configure the types of event hypothesis magnitude estimates to compute for newly computed event hypothesis locations by geographic region. (S-1655; Common)
Requirements Trace: SRD-106

3.2.8.1.2.2 The System shall provide the System Maintainer the capability to configure event hypothesis magnitude estimate calculation parameters by channel. (S-1656; Common)
Requirements Trace: SRD-106

3.2.8.1.2.3 The System shall provide the System Maintainer the capability to configure event hypothesis magnitude estimate calculation parameters by geographic region. (S-1657; Common)
Requirements Trace: SRD-106

3.2.8.1.3 Magnitude Estimation User Interfaces

3.2.8.1.3.1 The System shall provide the Analyst the capability to run event hypothesis magnitude estimate calculations with user selected input parameters. (S-1659; Common)
Requirements Trace: SRD-106, SRD-124, SRD-136

3.2.8.1.3.2 The System shall provide the Analyst the capability to select the type of magnitude to compute. (S-1660; Common)
Requirements Trace: SRD-110, SRD-124, SRD-136

3.2.8.1.3.3 The System shall provide the Analyst the capability to select the defining/non-defining state for a station magnitude estimate used for network magnitude estimation unless prohibited by the default defining/non-defining state. (S-1661; Common)
Requirements Trace: SRD-103, SRD-110, SRD-124, SRD-136

3.2.8.1.4 Magnitude Estimation Storage

3.2.8.1.4.1 The System shall store uncertainties for all event hypothesis magnitude estimates. (S-1663; Common)
Requirements Trace: SRD-108, SRD-189

3.2.8.1.4.2 The System shall store each single station magnitude estimate for each event hypothesis. (S-1664; Common)
Requirements Trace: SRD-106, SRD-189

3.2.8.1.4.3 The System shall store each network magnitude estimate for each event hypothesis. (S-1665; Common)
Requirements Trace: SRD-106, SRD-189

3.2.8.1.4.4 The System shall store the defining/non-defining state for each station magnitude associated to a stored event hypothesis. (S-1666; Common)
Requirements Trace: SRD-170, SRD-189

3.2.8.3 Moment Tensor Solutions
The System automatically computes moment tensor solutions for event hypotheses meeting specific criteria. Synthetic and observed seismograms used in moment tensor calculations measure ground motion in either displacement or velocity.

These criteria are specified using: event hypothesis location, event hypothesis magnitude, event hypothesis to station distance, and signal detection SNR for the phases used in computing the moment tensor.

3.2.8.3.1 Moment Tensor Solutions Processing

3.2.8.3.1.1 The System shall calculate Green functions using region specific 1D Earth models. (S-1684; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.2 The System shall calculate synthetic displacement waveforms. (S-1685; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.3 The System shall calculate synthetic velocity waveforms. (S-1686; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.4 The System shall calculate synthetic seismograms using Green functions computed using frequency-wavenumber integration. (S-1687; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.5 The System shall compute Green functions in real time while computing moment tensor solutions. (S-1688; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.6 The System shall apply the same filter to observed and synthetic waveforms during moment tensor calculations. (S-1689; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.7 The System shall compute moment tensor solutions using waveform data from one or more seismic stations. (S-1690; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.8 The System shall decompose moment tensor solutions into isotropic and deviatoric components. (S-1691; Common)
Requirements Trace: SRD-394

3.2.8.3.1.9 The System shall decompose deviatoric moment tensor solutions into double couple and compensated linear vector dipole (CLVD) components. (S-1692; Common)
Requirements Trace: SRD-394

3.2.8.3.1.10 The System shall compute the percentage of deviatoric moment tensor solutions belonging to the double couple components. (S-1693; Common)
Requirements Trace: SRD-394

3.2.8.3.1.11 The System shall compute shear phase radiation patterns for moment tensor solutions. (S-1694; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.12 The System shall compute compressional phase radiation patterns for moment tensor solutions. (S-1695; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.13 The System shall compute double couple fault planes from moment tensor solutions. (S-1696; Common)
Requirements Trace: SRD-394

3.2.8.3.1.14 The System shall compute the scalar seismic moment from moment tensor solutions. (S-1697; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.15 The System shall calculate station specific goodness of fit between theoretical and observed waveforms for moment tensor solutions. (S-1698; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.1.16 The System shall complete the calculation of a moment tensor solution for an event hypothesis in less than ten (10) minutes. (S-1699; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.2 Moment Tensor Solutions Support Interfaces

3.2.8.3.2.1 The System shall provide the System Maintainer the capability to configure the criteria used to determine if a moment tensor solution is automatically computed for an event hypothesis by geographic region. (S-1701; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.2.2 The System shall provide the System Maintainer the capability to configure the type of ground motion to use for moment tensor calculations by station. (S-1702; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.2.3 The System shall provide the System Maintainer the capability to configure which stations that have detected an event hypothesis are used in automatically initiated moment tensor calculations by geographic region. (S-1703; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.2.4 The System shall provide the System Maintainer the capability to configure the filter applied to observed and synthetic waveforms when computing moment tensor solutions. (S-1704; Common)
Requirements Trace: SRD-394, SRD-395

3.2.8.3.3 Moment Tensor Solutions User Interfaces

3.2.8.3.3.1 The System shall provide the Analyst the capability to compute a moment tensor solution for a selected event hypothesis and collection of seismic stations. (S-1706; Common)
Requirements Trace: SRD-136, SRD-394, SRD-395

3.2.8.3.3.2 The System shall provide the Analyst the capability to view the theoretical waveform overlaid on the observed waveform for a moment tensor solution. (S-1707; Common)
Requirements Trace: SRD-124, SRD-136, SRD-394, SRD-395

3.2.8.3.3.3 The System shall provide the Analyst the capability to view the station specific goodness of fit between theoretical and observed waveforms for moment tensor solutions.

(S-1708; Common)
Requirements Trace: SRD-124, SRD-136, SRD-394, SRD-395

3.2.8.3.3.4 The System shall provide the Analyst the capability to view double couple focal mechanisms. (S-1709; Common)
Requirements Trace: SRD-124, SRD-136, SRD-394

3.2.8.3.4 Moment Tensor Solutions Storage

3.2.8.3.4.1 The System shall store the type of ground motion used by moment tensor calculations. (S-1711; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.2 The System shall store the filter applied to observed and synthetic waveforms when computing moment tensor solutions. (S-1712; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.3 The System shall store the Green functions used to compute a moment tensor solution. (S-1713; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.4 The System shall store the Earth models used to compute a moment tensor solution. (S-1714; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.5 The System shall store the elements of moment tensor solutions. (S-1715; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.6 The System shall store the percentage of deviatoric moment tensor solutions belonging to the double couple components. (S-1716; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.7 The System shall store the double couple fault plane solution computed from a moment tensor solution. (S-1717; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.8 The System shall store the scalar seismic moment computed from a moment tensor solution. (S-1718; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.3.4.9 The System shall store the station specific goodness of fit between theoretical and observed waveforms for moment tensor solutions. (S-1719; Common)
Requirements Trace: SRD-189, SRD-394, SRD-395

3.2.8.4 Moment Tensor Source Type Plotting

Moment tensor source type plots display moment tensors in terms of two source type parameters, ε and k. ε is a measure of how much a deviatoric moment tensor deviates from a double couple source and k is a measure of volume change showing deviation from a purely explosive source. Hudson's source type plots involve a transformation on this 2D space and are described in the referenced paper.

Uncertainty bounds on ε and k are found using bootstrap resampling. New moment tensor solutions are created through bootstrapping. Using sampling with replacement, collections of stations contributing to the moment tensor solution are sampled from the stations used in the initial moment tensor solution. New moment tensor solutions are calculated for each sample, and ε and k are computed for each new moment tensor. This gives a representative distribution of ε and k from which uncertainty bounds are computed.

Ford, S. R., D. S. Dreger, and W. R. Walter (2009), Identifying isotropic events using a regional moment tensor inversion, J. Geophys. Res., 114, B01306, doi:10.1029/2008JB005743 <http://dx.doi.org/10.1029/2008JB005743>.

Hudson, J. A., R. G. Pearce, and R. M. Rogers (1989), Source type plot for inversion of the moment tensor, J. Geophys. Res., 94(B1), 765-774, doi:10.1029/JB094iB01p00765 <http://dx.doi.org/10.1029/JB094iB01p00765>.

3.2.8.4.1 Moment Tensor Source Type Plotting Processing

3.2.8.4.1.1 The System shall compute Hudson's ε value for moment tensor solutions. (S-1722; Common)
Requirements Trace: SRD-395

3.2.8.4.1.2 The System shall compute Hudson's k value for moment tensor solutions. (S-1723; Common)
Requirements Trace: SRD-395

3.2.8.4.1.3 The System shall use bootstrap resampling on the stations used in moment tensor solutions to estimate the distributions of ε for the moment tensor solutions. (S-1724; Common)
Requirements Trace: SRD-395

3.2.8.4.1.4 The System shall use bootstrap resampling on the stations used in moment tensor solutions to estimate the distributions of k for the moment tensor solutions. (S-1725; Common)
Requirements Trace: SRD-395

3.2.8.4.1.5 The System shall use the distributions of ε and k from bootstrap resampling on moment tensor solutions to compute the uncertainty bound on ε and k at a fixed confidence level for the moment tensor solutions. (S-1726; Common)
Requirements Trace: SRD-395

3.2.8.4.2 Moment Tensor Source Type Plotting User Interfaces

3.2.8.4.2.1 The System shall provide the Analyst the capability to select the number of samples to use during bootstrap resampling on moment tensor solutions to estimate the distributions of ε and k. (S-1728; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.2.2 The System shall provide the Analyst the capability to select the confidence level used to compute uncertainty bounds on ε and k for a moment tensor solution. (S-1729; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.2.3 The System shall provide the Analyst the capability to view transformed source type plots for moment tensor solutions as described in Hudson, Pearce, and Rogers (1989). (S-1730; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.2.4 The System shall provide the Analyst the capability to view the uncertainty bound on ε and k in transformed source type plots. (S-1731; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.2.5 The System shall provide the Analyst the capability to view multiple moment tensor solutions and their associated uncertainty bounds on ε and k on the same transformed source type plot. (S-1732; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.2.6 The System shall provide the Analyst the capability to select a group of event hypotheses for which moment tensor solutions and their associated uncertainty bounds on ε and k are plotted on a transformed source type plot. (S-1733; Common)
Requirements Trace: SRD-124, SRD-136, SRD-395

3.2.8.4.3 Moment Tensor Source Type Plotting Storage

3.2.8.4.3.1 The System shall store the ε value computed for moment tensor solutions. (S-1735; Common)
Requirements Trace: SRD-189, SRD-395

3.2.8.4.3.2 The System shall store the k value computed for moment tensor solutions. (S-1736; Common)
Requirements Trace: SRD-189, SRD-395

3.2.8.4.3.3 The System shall store the uncertainty bounds on ε and k computed for moment tensor solutions. (S-1737; Common)
Requirements Trace: SRD-189, SRD-395

3.2.8.4.3.4 The System shall store the confidence level of uncertainty bounds on ε and k computed for moment tensor solutions. (S-1738; Common)
Requirements Trace: SRD-189, SRD-395

3.2.8.6 Event Screening

3.2.8.6.1 Event Screening Processing

3.2.8.6.1.1 The System shall calculate a numerical metric for each configured screening criterion for each event. (S-5744; IDC only)
Requirements Trace: SRD-613

3.2.8.6.1.2 The System shall assign an overall screening category based on a combination of the individual screening criteria numerical metric scores. (S-5745; IDC only)
Requirements Trace: SRD-449

3.2.8.6.2 Event Screening Support Interfaces

3.2.8.6.2.1 The System shall provide the System Maintainer the capability to configure which screening criterion to calculate for each event. (S-5743; IDC only)
Requirements Trace: SRD-613

3.2.8.6.2.2 The System shall provide the System Maintainer the capability to configure which individual screening criteria numerical metric scores are combined to calculate an overall screening category. (S-5746; IDC only)
Requirements Trace: SRD-449

3.2.8.6.3 Event Screening User Interfaces

3.2.8.6.3.1 The System shall provide the Analyst the capability to mark signal detections associated to an event so as to exclude them from event screening calculations. (S-5827; IDC only)
Requirements Trace: SRD-623

3.2.9 Earth Propagation Models

3.2.9.1 Earth Model Predictions

For an event that occurs anywhere in the Earth, predictions of the following observables are needed.

Seismic body waves:

Phase-specific source-receiver travel time

Phase-specific horizontal slowness observed at a station

Phase-specific back-azimuth observed at a station

Frequency and phase-specific signal amplitude at a station

Seismic surface waves:

Frequency and phase specific source-receiver travel time

Frequency and phase specific horizontal slowness observed at a station

Frequency and phase specific back-azimuth observed at a station

Frequency and phase specific signal amplitude at a station

Infrasound waves:

Frequency and phase specific source-receiver travel time

Frequency and phase specific horizontal slowness observed at a station

Frequency and phase specific back-azimuth observed at a station

Frequency and phase specific signal amplitude at a station

Hydroacoustic waves:

Phase-specific source-receiver travel time

Phase-specific horizontal slowness observed at a station

Phase-specific back-azimuth observed at a station

Frequency and phase-specific signal amplitude at a station

Blockage at a station

Note: the only hydroacoustic phases are H and T

For travel time, horizontal slowness and back azimuth predictions, the following components are necessary: the predicted value, the uncertainty of the predicted value, and derivatives of the predicted value with respect to spatial position and time. For amplitude, only the predicted value and the associated uncertainty are needed. In the remainder of this preamble, the term prediction includes the associated uncertainty and derivatives (except for amplitude where the derivatives are not needed).

Predicted back azimuth is often assumed to be the azimuth of the great circle path from the receiver to the source. Because this prediction is based only on geometry and requires no geophysical knowledge at all, there are no requirements in this SSD related to computing back azimuth predictions in this manner. There are exceptions however. Ray tracing through Earth models where the seismic velocity varies with latitude and longitude can generate back azimuth predictions that do not coincide with the receiver-source great circle path and requirements related to phase-specific back azimuth prediction are included to cover that possibility.

The System may choose to implement acquisition of predictions in one of three basic ways. The choice of method is based on the state of knowledge of Earth properties, the computational cost of implementation, and the ability to verify the robustness and fidelity of the computed values.

1. On-the-fly integration of Earth properties

Fundamental properties of the Earth, which are generally stored in geophysical Earth models, are integrated along phase-specific ray paths from source to receiver. The System will compute predictions on-the-fly at the time that they are required. The Earth properties to be integrated for each prediction are:

Seismic body wave predictions: seismic velocity

Seismic surface wave predictions: group or phase velocity; or seismic velocity

Infrasound predictions: sound speed in air

Hydroacoustic predictions: sound speed in water (SOFAR channel)

Amplitude predictions: quality factor, Q

This approach is most appropriate when the integral is computationally inexpensive and the robustness of the computed predictions is easily verified. This approach is often adopted for predicting seismic surface wave travel-time and MDAC seismic body-wave amplitude, largely due to the fact the ray paths are well represented by simple great circle paths from source to receivers, rendering the path integral very simple to calculate.

2. Precomputed Prediction Lookup Tables

Similar to the first option, but predictions are pre-computed off-line for a grid of hypothetical source locations and stored in lookup tables. Actors external to the System may perform this step. Later, when predictions are required, their values are interpolated from the appropriate lookup table based on an assumed source location. The current system uses this approach for travel time prediction of teleseismic phases. This approach is also typically used for seismic body wave travel-time predictions computed using 3D velocity models because complex ray-tracing is required which can be computationally demanding and the robustness of the results can be challenging to verify.

3. Models derived directly from empirical observations

Empirical observations of the relevant parameter are statistically distilled into spatially varying estimates of the predicted values. No path integral through a model of Earth properties is performed, either on-the-fly or offline. Predicted values for a particular station-phase are obtained from a station-phase specific model by interpolation from the model at the assumed source location. This approach is often used for body wave amplitude predictions because the state of knowledge about the distribution of Q in the Earth does not warrant the complexity of ray tracing, even along great circle paths.

Empirical corrections to basemodel predictions

So far, the discussion has focused on models that are capable of producing predictions for events anywhere on the Earth, even regions where events have never been recorded before. To improve

these predictions for events in regions with a substantial history of recorded events, empirically derived corrections for earth model predictions are developed. These corrections describe how observed values of a phase at a station for events in a particular region differ from basemodel predictions. Corrections are applied to values predicted from basemodels to improve the match between the predicted values and historical observations.

Signal predictions may be computed either by on-the-fly integration of Earth properties or by interpolation of values from precomputed lookup tables.

Earth model predictions are used during: predicting arrivals, event hypothesis magnitude estimation, event hypothesis location, and signal association.

3.2.9.1.2 Earth Model Predictions Processing

3.2.9.1.2.1 The System shall use correction surfaces to compute corrections to earth model predictions. (S-1776; Common)
Requirements Trace: SRD-203, SRD-204, SRD-212

3.2.9.1.2.2 The System shall apply earth model prediction corrections to earth model predictions computed from basemodels. (S-1777; Common)
Requirements Trace: SRD-203, SRD-204, SRD-212

3.2.9.1.2.3 The System shall apply empirical Master Event Corrections by station and phase to earth model predictions and prediction uncertainties. (S-1778; Common)
Requirements Trace: SRD-203

3.2.9.1.2.4 The System shall compute predicted slowness using a one-dimensional phase-specific basemodel. (S-1779; Common)
Requirements Trace: SRD-197

3.2.9.1.2.5 The System shall compute phase-specific slowness predictions using a velocity model where the velocity of the Earth varies as a function of depth but not latitude or longitude. (S-1780; Common)
Requirements Trace: SRD-197

3.2.9.1.2.6 The System shall compute the uncertainties of predicted slowness computed using a one-dimensional phase-specific basemodel. (S-1781; Common)
Requirements Trace: SRD-197

3.2.9.1.2.7 The System shall compute the uncertainty of phase-specific slowness predictions using a velocity model where the velocity of the Earth varies as a function of depth but not latitude or longitude. (S-1782; Common)
Requirements Trace: SRD-197

3.2.9.1.2.8 The System shall compute predicted slowness using a three-dimensional phase-specific basemodel. (S-1783; Common)
Requirements Trace: SRD-198

3.2.9.1.2.9 The System shall compute phase-specific slowness predictions using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1784; Common)
Requirements Trace: SRD-198

3.2.9.1.2.10 The System shall compute the uncertainties of predicted slowness computed using a three-dimensional phase-specific basemodel. (S-1785; Common)
Requirements Trace: SRD-198

3.2.9.1.2.11 The System shall compute the uncertainty of phase-specific slowness predictions using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1786; Common)
Requirements Trace: SRD-198

3.2.9.1.2.12 The System shall compute predicted azimuths using a three-dimensional phase-specific basemodel. (S-1787; Common)
Requirements Trace: SRD-199

3.2.9.1.2.13 The System shall compute phase-specific azimuth predictions using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1788; Common)
Requirements Trace: SRD-199

3.2.9.1.2.14 The System shall compute the uncertainties of predicted azimuths computed using a three-dimensional phase-specific basemodel. (S-1789; Common)
Requirements Trace: SRD-199

3.2.9.1.2.15 The System shall compute uncertainty of phase-specific azimuth predictions using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1790; Common)
Requirements Trace: SRD-199

3.2.9.1.2.16 The System shall use a seasonal climatological model for computing azimuths for infrasound data. (S-5829; Common)
Requirements Trace: SRD-199

3.2.9.1.2.17 The System shall use a daily and hourly varying meteorological model for computing azimuths in infrasound data. (S-5830; Common)
Requirements Trace: SRD-199

3.2.9.1.2.18 The System shall compute predicted travel-times using a one-dimensional phase-specific basemodel. (S-1791; Common)
Requirements Trace: SRD-200

3.2.9.1.2.19 The System shall compute phase-specific travel-time predictions using a velocity model where the velocity of the Earth varies as a function of depth but not latitude or longitude. (S-1792; Common)
Requirements Trace: SRD-200

3.2.9.1.2.20 The System shall compute the uncertainties of predicted travel-times computed using a one-dimensional phase-specific basemodel. (S-1793; Common)
Requirements Trace: SRD-200

3.2.9.1.2.21 The System shall compute the uncertainty of phase-specific travel-time predictions using a velocity model where the velocity of the Earth varies as a function of depth but not latitude or longitude. (S-1794; Common)
Requirements Trace: SRD-200

3.2.9.1.2.22 The System shall compute predicted travel-times using a two-dimensional phase-specific basemodel. (S-1795; Common)
Requirements Trace: SRD-201, SRD-206

3.2.9.1.2.23 The System shall compute phase-specific travel-time predictions using a velocity model where the velocity of the Earth varies as a function of latitude and longitude but not depth. (S-1796; Common)
Requirements Trace: SRD-201, SRD-206

3.2.9.1.2.24 The System shall compute predicted travel time of Rayleigh waves and Love waves using frequency-specific group and phase velocity models where the group/phase velocity varies as a function of latitude and longitude but not depth. (S-1797; Common)
Requirements Trace: SRD-201, SRD-206

3.2.9.1.2.25 The System shall compute the uncertainties of predicted travel-times computed using a two-dimensional phase-specific basemodel. (S-1798; Common)
Requirements Trace: SRD-201

3.2.9.1.2.26 The System shall compute phase-specific uncertainty of predicted travel-time using a velocity model where the velocity of the Earth varies as a function of latitude and longitude but not depth. (S-1799; Common)
Requirements Trace: SRD-201

3.2.9.1.2.27 The System shall compute uncertainty of predicted travel time of Rayleigh waves and Love waves using frequency-specific group and phase velocity models where the group/phase velocity varies as a function of latitude and longitude but not depth. (S-1800; Common)
Requirements Trace: SRD-201

3.2.9.1.2.28 The System shall compute predicted travel-times using a three-dimensional phase-specific basemodel. (S-1801; Common)
Requirements Trace: SRD-202, SRD-206

3.2.9.1.2.29 The System shall compute phase-specific travel-time predictions using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1802; Common)
Requirements Trace: SRD-202, SRD-206

3.2.9.1.2.30 The System shall compute the uncertainties of predicted travel-times computed using a three-dimensional phase-specific basemodel. (S-1803; Common)
Requirements Trace: SRD-202

3.2.9.1.2.31 The System shall compute phase-specific uncertainty of predicted travel-time using a velocity model where the velocity of the Earth varies as a function of latitude, longitude, and depth. (S-1804; Common)
Requirements Trace: SRD-202

3.2.9.1.3 Earth Model Predictions Support Interfaces

3.2.9.1.3.1 The System shall provide the System Maintainer the capability to configure the default earth models used for earth model predictions per observation type. (S-1806; Common)
Requirements Trace: SRD-71

3.2.9.1.3.2 The System shall provide the System Maintainer the capability to configure the default earth models used for earth model predictions per station, phase, frequency and channel. (S-1807; Common)
Requirements Trace: SRD-71

3.2.9.1.3.3 The System shall provide the System Maintainer the capability to configure station, phase, and frequency dependent correction surfaces for earth model prediction corrections. (S-1808; Common)
Requirements Trace: SRD-203, SRD-204, SRD-212

3.2.9.1.3.4 The System shall provide the System Maintainer the capability to configure earth model parameters. (S-1809; Common)
Requirements Trace: SRD-137

3.2.9.1.4 Earth Model Predictions User Interfaces

3.2.9.1.4.1 The System shall provide the Analyst the capability to select the earth model used for an earth model prediction. (S-1811; Common)
Requirements Trace: SRD-124, SRD-136, SRD-137, SRD-197, SRD-198, SRD-199, SRD-200, SRD-201, SRD-202, SRD-209, SRD-211

3.2.9.1.4.2 The System shall provide the Analyst the capability to select the correction surface used for correcting an earth model prediction. (S-1812; Common)
Requirements Trace: SRD-124, SRD-136, SRD-203, SRD-204, SRD-212

3.2.9.1.4.3 The System shall provide the Analyst the capability to apply Master Event Corrections. (S-1813; Common)
Requirements Trace: SRD-203

3.2.9.1.4.4 The System shall provide the Analyst the capability to view theoretical arrival times for an Analyst selected set of seismic phases. (S-1814; Common)
Requirements Trace: SRD-124, SRD-136

3.2.9.1.4.5 The System shall provide the Analyst the capability to view the model parameters used to predict signal propagation. (S-5852; Common)
Requirements Trace: SRD-124, SRD-136

3.2.9.1.4.6 The System shall provide the Analyst the capability to view the earth models on a map. (S-5853; Common)
Requirements Trace: SRD-124, SRD-136

3.2.9.1.5 Earth Model Predictions Storage

3.2.9.1.5.1 The System shall store the earth model and version used to compute an earth model prediction. (S-1816; Common)
Requirements Trace: SRD-189, SRD-197, SRD-198, SRD-199, SRD-200, SRD-201, SRD-202, SRD-209, SRD-211

3.2.9.1.5.2 The System shall store the corrections applied to earth model predictions. (S-1817; Common)
Requirements Trace: SRD-189, SRD-203, SRD-204, SRD-212

3.2.9.1.5.3 The System shall store the correction surface used to correct an earth model prediction. (S-1818; Common)
Requirements Trace: SRD-189, SRD-203, SRD-204, SRD-212

3.2.9.1.5.4 The System shall store the predicted slowness computed from a basemodel. (S-1819; Common)
Requirements Trace: SRD-189, SRD-197, SRD-198

3.2.9.1.5.5 The System shall store the uncertainties of a predicted slowness computed using a basemodel. (S-1820; Common)
Requirements Trace: SRD-189, SRD-197, SRD-198

3.2.9.1.5.6 The System shall store the predicted azimuths computed using a phase-specific basemodel. (S-1821; Common)
Requirements Trace: SRD-189, SRD-199

3.2.9.1.5.7 The System shall store the uncertainties of predicted azimuths computed using a basemodel. (S-1822; Common)
Requirements Trace: SRD-189, SRD-199

3.2.9.1.5.8 The System shall store the predicted travel-times computed from a basemodel. (S-1823; Common)
Requirements Trace: SRD-189, SRD-200, SRD-201, SRD-202

3.2.9.1.5.9 The System shall store the uncertainties of predicted travel-times computed using a basemodel. (S-1824; Common)
Requirements Trace: SRD-189, SRD-200, SRD-201, SRD-202

3.2.9.1.5.10 The System shall store global meteorological data. (S-5714; Common)
Requirements Trace: SRD-189, SRD-610

3.2.9.1.5.11 The System shall store wind velocity (including uncertainty) computed from meteorological models. (S-5715; Common)
Requirements Trace: SRD-189, SRD-610

3.2.9.1.5.12 The System shall store temperature (including uncertainty) computed from meteorological models. (S-5716; Common)
Requirements Trace: SRD-189, SRD-610

3.2.9.1.5.13 The System shall store gravity wave corrections to temperature predictions. (S-5717; Common)
Requirements Trace: SRD-189, SRD-610

3.2.9.2 Amplitude Attenuation Basemodels
Amplitude attenuation basemodels describe how signal amplitudes decay as a result of propagating through physical media from sources to receivers.

Three classes of amplitude attenuation basemodels are available:

- One-dimensional basemodels: account for distance between source and receiver.
- Two-dimensional basemodels: account for the great circle signal propagation path between source and receiver.
- Three-dimensional basemodels: account for the 3D signal propagation path between source and receiver.

Each type of amplitude attenuation basemodel is dependent on signal phase and frequency.

3.2.9.2.1 Amplitude Attenuation Basemodels Processing

3.2.9.2.1.1 The System shall compute predicted amplitude attenuation from phase and frequency dependent one-dimensional basemodels. (S-1827; Common)
Requirements Trace: SRD-209

3.2.9.2.1.2 The System shall compute amplitude correction factors using Q models where Q in the Earth varies as a function of phase, frequency and depth, but not latitude or longitude. (S-1828; Common)
Requirements Trace: SRD-209

3.2.9.2.1.3 The System shall compute predicted amplitude attenuation uncertainties from phase and frequency dependent one-dimensional basemodels. (S-1829; Common)
Requirements Trace: SRD-209

3.2.9.2.1.4 The System shall compute the uncertainty of amplitude correction factors computed using Q models where Q in the Earth varies as a function of phase, frequency and depth, but not latitude or longitude. (S-1830; Common)
Requirements Trace: SRD-209

3.2.9.2.1.5 The System shall compute predicted amplitude attenuation from frequency dependent three-dimensional basemodels. (S-1837; Common)
Requirements Trace: SRD-211

3.2.9.2.1.6 The System shall compute amplitude correction factors using Q models where Q in the Earth varies as a function of phase, frequency, latitude, longitude and depth. (S-1838; Common)
Requirements Trace: SRD-211

3.2.9.2.1.7 The System shall compute predicted amplitude attenuation uncertainties from frequency dependent three-dimensional basemodels. (S-1839; Common)
Requirements Trace: SRD-211

3.2.9.2.1.8 The System shall compute the uncertainty of amplitude correction factors computed using Q models where Q in the Earth varies as a function of phase, frequency, latitude, longitude and depth. (S-1840; Common)
Requirements Trace: SRD-211

3.2.9.2.1.9 The System shall compute predicted signal amplitude decay from geometric spreading as a function of phase and distance from the source. (S-3041; Common)
Requirements Trace: SRD-209

3.2.9.2.1.10 The System shall compute uncertainty of predicted signal amplitude decay from geometric spreading as a function of phase and distance from the source. (S-3042; Common)
Requirements Trace: SRD-209

3.2.9.2.1.11 The System shall compute predicted signal amplitude decay from geometric spreading as a function of phase, frequency, and propagation path from the source. (S-3043; Common)
Requirements Trace: SRD-211

3.2.9.2.1.12 The System shall compute uncertainty of predicted signal amplitude decay from geometric spreading as a function of phase, frequency, and propagation path from the source. (S-3044; Common)
Requirements Trace: SRD-211

3.2.9.2.1.13 The System shall correct signal amplitudes for decay from geometric spreading when applying amplitude attenuation corrections. (S-3045; Common)
Requirements Trace: SRD-209, SRD-211

3.2.9.2.2 Amplitude Attenuation Basemodels Storage

3.2.9.2.2.1 The System shall store predicted amplitude attenuation. (S-1842; Common)
Requirements Trace: SRD-189, SRD-209, SRD-211

3.2.9.2.2.2 The System shall store predicted amplitude attenuation uncertainties. (S-1843; Common)
Requirements Trace: SRD-189, SRD-209, SRD-211

3.2.9.3 Basemodel Temporal Variation

Variations in atmospheric and oceanic conditions lead to a time dependence in the amplitude attenuation of infrasonic and hydroacoustic signals. Infrasonic signals attenuate according to atmospheric wind conditions.

Hydroacoustic signals can travel global distances in the SOFAR channel, but attenuate more outside of this channel. Depth of the SOFAR channel is related to ocean temperature.

Atmospheric model resolution for use in the System should be hourly or finer to support diurnal variations and daily, weekly, or monthly to support seasonal variations. Two types of climate models capturing temporal variations are available.

- Climatological models average diurnal or seasonal conditions over a period of time
- Meteorological models cover conditions for specific time periods

Propagation path specific temporal variations can be computed by using signal propagation velocity to sample the climate model along points on the propagation path at the time the signal crosses those points.

Time dependent travel time and/or amplitude attenuation models are used to compute: predicted signal detections, distance corrected signal detection feature measurements (such as amplitude), and event hypothesis locations.

Temporal dependence is unneeded for seismic signals since changes in geological structures occur much slower than changes in water and air.

3.2.9.3.1 Basemodel Temporal Variation Processing

3.2.9.3.1.1 The System shall compute time dependent predicted amplitude attenuation for infrasonic signals. (S-1846; Common)
Requirements Trace: SRD-213

3.2.9.3.1.2 The System shall compute time dependent predicted amplitude attenuation uncertainties for infrasonic signals. (S-1847; Common)
Requirements Trace: SRD-213

3.2.9.3.1.3 The System shall compute time dependent predicted amplitude attenuation for hydroacoustic signals. (S-1848; Common)
Requirements Trace: SRD-213

3.2.9.3.1.4 The System shall compute time dependent predicted amplitude attenuation uncertainties for hydroacoustic signals. (S-1849; Common)
Requirements Trace: SRD-213

3.2.9.3.1.5 The System shall compute wind velocity predictions using meteorological models that vary as a function of latitude, longitude, altitude, and time. (S-5615; Common)
Requirements Trace: SRD-412, SRD-418

3.2.9.3.1.6 The System shall compute uncertainties of predicted wind velocities computed using meteorological models. (S-5616; Common)
Requirements Trace: SRD-412, SRD-418

3.2.9.3.1.7 The System shall compute corrections to wind velocity predictions based on a model for atmospheric gravity waves. (S-5652; Common)
Requirements Trace: SRD-418

3.2.9.3.1.8 The System shall compute atmospheric temperature predictions using meteorological models that vary as a function of latitude, longitude, altitude, and time. (S-5617; Common)
Requirements Trace: SRD-412, SRD-418

3.2.9.3.1.9 The System shall compute uncertainties of predicted atmospheric temperatures computed using meteorological models. (S-5618; Common)
Requirements Trace: SRD-418

3.2.9.3.1.10 The System shall compute corrections to atmospheric temperature predictions based on a model for atmospheric gravity waves. (S-5653; Common)
Requirements Trace: SRD-418

3.2.9.3.1.11 The system shall compute an infrasound propagation model using gravity wave corrected wind velocity and atmospheric temperature predictions. (S-5654; Common)
Requirements Trace: SRD-418

3.2.9.3.1.12 The system shall compute an infrasound propagation model that incorporates high resolution meteorological data. (S-5656; Common)
Requirements Trace: SRD-419

3.2.9.3.1.13 The System shall incorporate monthly variations in hydroacoustic blockage. (S-1851; Common)
Requirements Trace: SRD-205

3.2.9.3.1.14 The System shall incorporate monthly variations in travel time for hydroacoustic data. (S-1852; Common)
Requirements Trace: SRD-206

3.2.9.3.1.15 The System shall use a seasonal climatological model for computing travel times in infrasound data. (S-1853; Common)
Requirements Trace: SRD-206

3.2.9.3.1.16 The system shall compute infrasound travel-time, slowness, and attenuation using an infrasound propagation model. (S-5655; Common)
Requirements Trace: SRD-419

3.2.9.3.1.17 The system shall compute uncertainties of infrasound travel-time, slowness, and attenuation using an infrasound propagation model. (S-5657; Common)
Requirements Trace: SRD-419

3.2.9.3.1.18 The System shall use a daily and hourly varying meteorological model for computing travel times in infrasound data. (S-5828; Common)
Requirements Trace: SRD-206

3.2.9.3.1.19 The System shall model thermospheric phases when computing infrasonic travel times. (S-1855; Common)
Requirements Trace: SRD-206

3.2.9.3.1.20 The System shall model tropospheric phases when computing infrasonic travel times. (S-5772; Common)
Requirements Trace: SRD-206

3.2.9.3.1.21 The System shall model stratospheric phases when computing infrasonic travel times. (S-5773; Common)
Requirements Trace: SRD-206

3.2.9.3.1.22 The System shall model direct phases when computing infrasonic travel times. (S-5774; Common)
Requirements Trace: SRD-206

3.2.9.3.1.23 The System shall model Lamb waves when computing travel times in infrasound data. (S-1856; Common)
Requirements Trace: SRD-206

3.2.9.3.1.24 The System shall compute uncertainties of predicted atmospheric temperatures computed using meteorological models. (S-5619; Common)
Requirements Trace: SRD-412

3.2.9.3.2 Basemodel Temporal Variation User Interfaces

3.2.9.3.2.1 The System shall provide the System User the capability to view temporal amplitude attenuation for infrasonic and hydroacoustic signals. (S-1850; Common)
Requirements Trace: SRD-213

3.2.10 Processing Stage Workflow
There are groups of operations the System runs to prepare for future system processing stages whenever particular triggering events occur.

Operations available for grouping include: time domain measurements, frequency domain measurements, beamforming, magnitude calculations, phase identification, and signal detection association.

Triggering events include: completion of a particular processing stage, initiating magnitude estimation calculation, upon Analyst initiation for late arriving data, upon Analyst initiation for

one or more Analyst modified arrivals, upon Analyst initiation for one or more Analyst created arrivals, upon Analyst initiation for one or more Analyst modified events, and upon Analyst initiation for one or more Analyst created events.

3.2.10.1 Processing Stage Workflow Processing

3.2.10.1.1 The System shall set the processing stage workflow status of a processing time interval to reflect analysis activity. (S-1859; Common)
Requirements Trace: SRD-403

3.2.10.1.2 The System shall set the processing stage workflow status of events to reflect analysis activity. (S-2588; Common)
Requirements Trace: SRD-403

3.2.10.1.3 The System shall process waveform data within a configurable processing time interval when a configurable percentage of data is available. (S-1860; Common)
Requirements Trace: SRD-276

3.2.10.1.4 The System shall process all available alphanumeric data within a configurable processing time interval. (S-1861; Common)
Requirements Trace: SRD-276

3.2.10.1.5 The System shall run a previously configured group of operations whenever the triggering event for that group of operations occurs. (S-1862; Common)
Requirements Trace: SRD-63, SRD-81, SRD-263, SRD-276, SRD-402

3.2.10.1.6 The System shall by default invoke the same algorithms during interactive processing as those used in automated processing. (S-5621; Common)
Requirements Trace: SRD-135

3.2.10.2 Processing Stage Workflow Support Interfaces

3.2.10.2.1 The System shall provide the System Maintainer the capability to configure the processing time interval and percentage of data available for waveform data processing. (S-1865; Common)
Requirements Trace: SRD-277

3.2.10.2.2 The System shall provide the System Maintainer the capability to configure the processing time interval for event hypothesis data processing. (S-1866; Common)
Requirements Trace: SRD-277

3.2.10.2.3 The System shall provide the System Maintainer the capability to configure the initiation of automatic processing based on time intervals. (S-1867; Common)
Requirements Trace: SRD-217, SRD-402

3.2.10.2.4 The System shall provide the System Maintainer the capability to configure the initiation of automatic processing based on data availability. (S-1868; Common)
Requirements Trace: SRD-217, SRD-280, SRD-402

3.2.10.2.5 The System shall provide the System Maintainer the capability to configure the initiation of automatic processing based on processing stage completion. (S-1869; Common)
Requirements Trace: SRD-217, SRD-402

3.2.10.2.6 The System shall provide the System Maintainer the capability to configure groups of operations to run whenever a triggering event specified by the System Maintainer occurs. (S-1870; Common)
Requirements Trace: SRD-63, SRD-81, SRD-263, SRD-276, SRD-402

3.2.10.2.7 The System shall provide the System Maintainer the capability to configure whether the Analyst can interrupt automated event hypothesis processing. (S-5557; Common)
Requirements Trace: SRD-276

3.2.10.3 Processing Stage Workflow User Interfaces

3.2.10.3.1 The System shall provide the Analyst the capability to set the processing stage workflow status of a processing time interval. (S-2589; Common)
Requirements Trace: SRD-403

3.2.10.3.2 The System shall provide the Analyst the capability to set the processing stage workflow status of an event. (S-2590; Common)
Requirements Trace: SRD-403

3.2.10.3.3 The System shall provide the Analyst the capability to interrupt automated event hypothesis processing to analyze data if configured. (S-1872; Common)
Requirements Trace: SRD-124, SRD-136, SRD-140

3.2.10.3.4 The System shall provide the System User the capability to view the processing stage workflow status of processing time intervals. (S-1874; Common)
Requirements Trace: SRD-403

3.2.10.3.5 The System shall provide the Analyst the capability to allocate analysis time intervals for a processing stage. (S-1875; Common)
Requirements Trace: SRD-404

3.2.10.3.6 The System shall notify Analysts working in a common processing stage if they are concurrently modifying event hypotheses for an event. (S-1876; Common)
Requirements Trace: SRD-402

3.2.10.3.7 The System shall notify Analysts working in a common processing stage if they are concurrently modifying signal detections in the same analysis time interval. (S-1877; Common)
Requirements Trace: SRD-402

3.2.10.3.8 The System shall provide the Analyst the capability to analyze any data stored on the System where station configuration data exists. (S-1879; Common)
Requirements Trace: SRD-124, SRD-136, SRD-218

3.2.10.3.9 The System shall provide the System User the capability to retrieve stored processing results from computations. (S-2040; Common)
Requirements Trace: SRD-124, SRD-136, SRD-169

3.2.10.4 Processing Stage Storage

3.2.10.4.1 The System shall store all data and derived processing results to non-volatile memory / persistent storage as soon as the data and/or derived processing results are available. (S-2223; Common)
Requirements Trace: SRD-271

3.2.10.4.2 The System shall preserve analyst processing results. (S-1863; Common)
Requirements Trace: SRD-63, SRD-79, SRD-83, SRD-263

3.2.10.4.3 The System shall store automatic and interactive processing results in the database for use by subsequent processing. (S-2043; Common)
Requirements Trace: SRD-169, SRD-189

3.2.11 Interactive Analysis
Interactive Analysis provides System Users the capability to review, refine, correct, and display the processing results generated by pipeline processing or interactive analysis.

NOTE: Interactive analysis includes but is not limited to:

- Manual signal detection
- Flexible trace windowing and manipulation (e.g., zoom, scale)
- Channel sorting, manipulation, and expansion of arrays and three-component data
- Filtering
- Spectral analysis
- fk analysis
- Beamforming (both fk and event beams)
- 2-D and 3-D component rotation
- Amplitude and period measurements
- Single and multi-station location
- Prediction of most of the known seismic phases (approximately 75 phases)
- Mapping (e.g., displaying results on maps)

3.2.11.1 Waveform Interaction

3.2.11.1.1 Waveform Interaction Processing

3.2.11.1.1.1 The System shall display 24 hours of continuous waveform data before the waveform displays flatline. (S-1885; Common)
Requirements Trace: SRD-124

3.2.11.1.2 Waveform Interaction Support Interfaces

3.2.11.1.2.1 The System shall provide the System Maintainer the capability to configure the visibility of waveforms for interactive analysis by station as default, available on demand, and limited analysis. (S-2595; Common)
Requirements Trace: SRD-124, SRD-278

3.2.11.1.2.2 The System shall provide the System Maintainer the capability to automatically execute processing of waveform data (i.e., data acquisition, data processing, and data storage). (S-2173; Common)
Requirements Trace: SRD-356

3.2.11.1.3 Waveform Interaction User Interfaces

3.2.11.1.3.1 The System shall provide the Analyst the capability to select for analysis a time block of continuous waveform data. (S-1887; Common)
Requirements Trace: SRD-124, SRD-127, SRD-136

3.2.11.1.3.2 The System shall provide the Analyst the capability to analyze continuous waveform data from within a selected time block. (S-1888; Common)
Requirements Trace: SRD-124, SRD-127, SRD-136

3.2.11.1.3.3 The System shall provide the Analyst the capability to access late-arriving waveform data within one (1) minute of receipt by the Data Processing Partition. (S-2604; Common)
Requirements Trace: SRD-265

3.2.11.1.3.4 The System shall provide the Analyst the capability to overlay waveforms with other waveforms. (S-1889; Common)
Requirements Trace: SRD-124, SRD-133, SRD-136

3.2.11.1.3.5 The System shall provide the Analyst the capability to select the amount of waveform data to view before waveform displays flatline. (S-1890; Common)
Requirements Trace: SRD-124

3.2.11.1.3.6 The System shall provide the Analyst the capability to select if waveform displays show flatlined waveforms. (S-1891; Common)
Requirements Trace: SRD-124

3.2.11.1.3.7 The System shall provide the Analyst the capability to sort channels based on distance from event. (S-1893; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.8 The System shall provide the Analyst the capability to sort channels based on station name. (S-1894; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.9 The System shall provide the Analyst the capability to sort channels based on station probability of detection for an event. (S-1895; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.10 The System shall provide the Analyst the capability to show all channels for a beam. (S-1896; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.11 The System shall provide the Analyst the capability to show all channels for an array. (S-1897; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.12 The System shall provide the Analyst the capability to show all channels for a 3-component station. (S-1898; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.13 The System shall provide the Analyst the capability to zoom the time axis of the waveform display. (S-1899; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.14 The System shall provide the Analyst the capability to scale the amplitude of individual displayed waveforms. (S-1900; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.15 The System shall provide the Analyst the capability to display a group of waveforms with their amplitudes scaled relative to the amplitudes of the other waveforms in the group. (S-1901; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.16 The System shall provide the Analyst the capability to adjust the height of an individual waveform display. (S-1902; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.17 The System shall provide the Analyst the capability to scroll waveform data along the time axis. (S-1903; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.18 The System shall provide the Analyst the capability to scroll the channels shown on the waveform display. (S-1904; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.19 The System shall provide the Analyst the capability to select the number of channels that are simultaneously visible on the waveform display. (S-1905; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.20 The System shall provide the Analyst the capability to time align waveforms based on observed signal detections for a user selected phase. (S-1906; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.21 The System shall provide the Analyst the capability to time align waveforms based on real time. (S-1907; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.22 The System shall provide the Analyst the capability to align waveforms based on theoretical signal detections for a user selected phase. (S-1908; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.1.3.23 The System shall provide the Analyst the capability to select signal detections as processing input based on a time interval for an entire network during an analysis session. (S-1927; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.11.1.3.24 The System shall provide the Analyst the capability to select signal detections as processing input based on a time interval for a selected subset of stations during an analysis session. (S-1928; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.11.1.3.25 The System shall provide the Analyst the capability to individually select signal detections as processing input during an analysis session. (S-1929; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138, SRD-142

3.2.11.2 Event Interaction

3.2.11.2.1 Event Interaction Support Interfaces

3.2.11.2.1.1 The System shall provide the System Maintainer the capability to configure when multiple Analysts are allowed to concurrently process data based on processing stage. (S-1913; Common)
Requirements Trace: SRD-274

3.2.11.2.2 Event Interaction User Interfaces

3.2.11.2.2.1 The System shall provide the Analyst the capability to relocate event hypotheses. (S-1615; Common)
Requirements Trace: SRD-124, SRD-136

3.2.11.2.2.2 The System shall provide the Analyst the capability to process data without altering another Analyst's existing solution. (S-1915; Common)
Requirements Trace: SRD-124, SRD-136, SRD-274

3.2.11.2.2.3 The System shall provide the Analyst the capability to select and retrieve a reference event hypothesis and associated waveform data. (S-1916; Common)
Requirements Trace: SRD-124, SRD-136, SRD-139, SRD-141

3.2.11.2.2.4 The System shall provide the Analyst the capability to mark an event as a reference event. (S-1917; Common)
Requirements Trace: SRD-124, SRD-136, SRD-141

3.2.11.2.2.5 The System shall provide the Analyst the capability to view a list of reference events. (S-1918; Common)
Requirements Trace: SRD-124, SRD-136, SRD-141

3.2.11.2.2.6 The System shall provide the Analyst the capability to designate the preferred event hypothesis for each event. (S-1616; Common)
Requirements Trace: SRD-95, SRD-124, SRD-136, SRD-402

3.2.11.2.2.7 The System shall provide the Analyst the capability to analyze events in any order. (S-1919; Common)
Requirements Trace: SRD-124, SRD-128, SRD-136

3.2.11.2.2.8 The System shall provide the Analyst the capability to view any saved event hypothesis. (S-1920; Common)
Requirements Trace: SRD-124, SRD-133, SRD-136, SRD-139, SRD-140

3.2.11.2.2.9 The System shall provide the Analyst the capability to enter comments for an event hypothesis. (S-1921; Common)
Requirements Trace: SRD-124, SRD-136, SRD-400

3.2.11.2.2.10 The System shall provide the Analyst the capability to view comments for an event hypothesis. (S-1922; Common)
Requirements Trace: SRD-124, SRD-136, SRD-400

3.2.11.2.2.11 The System shall provide the Analyst the capability to provide feedback on other Analysts' work. (S-1923; Common)
Requirements Trace: SRD-124, SRD-133, SRD-136

3.2.11.2.2.12 The System shall provide the Analyst the capability to view feedback provided by an Analyst. (S-5556; Common)
Requirements Trace: SRD-133

3.2.11.2.2.13 The System shall notify the Analyst of feedback provided by another Analyst. (S-1924; Common)
Requirements Trace: SRD-133

3.2.11.2.2.14 The System shall provide the Analyst the capability to view the complete history of an event. (S-1926; Common)
Requirements Trace: SRD-124, SRD-136, SRD-139

3.2.11.2.2.15 The System shall provide the Duty Officer the capability to remotely review waveform and alphanumeric data and screenshots from any location. (S-1931; Common)
Requirements Trace: SRD-328

3.2.11.2.2.16 The System shall provide the Researcher the capability to remotely view (read only) waveform processing results from any location. (S-5669; IDC only)
Requirements Trace: SRD-328

3.2.11.2.2.17 The System shall provide the Analyst the capability to iteratively undo/redo back to the last saved state of an event. (S-1892; Common)
Requirements Trace: SRD-124, SRD-136, SRD-287

3.2.11.2.3 Event Interaction Storage

3.2.11.2.3.1 The System shall provide the Analyst the capability to store new event hypotheses created during interactive processing. (S-1930; Common)
Requirements Trace: SRD-124, SRD-136, SRD-138

3.2.11.2.3.2 The System shall store a preferred event hypothesis for each event for each processing stage. (S-1625; Common)
Requirements Trace: SRD-95, SRD-189

3.2.11.2.3.3 The System shall store the processing stage during which each event hypothesis location was created. (S-1626; Common)
Requirements Trace: SRD-96, SRD-189, SRD-448

3.2.11.2.3.4 The System shall store the processing stage during which an event hypothesis is modified. (S-1627; Common)
Requirements Trace: SRD-96, SRD-189, SRD-448

3.2.11.2.3.5 The System shall store the processing stage that rejected an event. (S-1628; Common)
Requirements Trace: SRD-96, SRD-189, SRD-448

3.2.11.3 Hierarchical Clustering

The System uses agglomerative hierarchical clustering to compare similarity of multiple waveforms recorded by the same channel.

Agglomerative hierarchical clustering distance algorithms are: nearest neighbor, furthest neighbor, median distance, group mean distance, central distance, minimum variance, and general weighted distance.

Agglomerative hierarchical clustering threshold selection algorithms are: Mojena, intracluster variance, and cophenetic.

3.2.11.3.1 Hierarchical Clustering Processing

3.2.11.3.1.1 The System shall create agglomerative hierarchical clusters of sets of waveforms based on the maximum cross correlation coefficient of each pair of waveforms in the set. (S-1934; Common)
Requirements Trace: SRD-125

3.2.11.3.1.2 The System shall use the agglomerative hierarchical clustering distance algorithms while agglomerative hierarchical clustering. (S-1935; Common)
Requirements Trace: SRD-125

3.2.11.3.1.3 The System shall automatically choose a correlation threshold value to determine clusters when forming a dendrogram. (S-1936; Common)
Requirements Trace: SRD-125

3.2.11.3.2 Hierarchical Clustering User Interfaces

3.2.11.3.2.1 The System shall provide the Analyst the capability to view the results of correlation analysis in a dendrogram. (S-1938; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.11.3.2.2 The System shall provide the Analyst the capability to select the weights used by the general weighted distance clustering algorithm. (S-1939; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.11.3.2.3 The System shall provide the Analyst the capability to select the agglomerative hierarchical clustering distance algorithm to use in agglomerative hierarchical clustering. (S-1940; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.11.3.2.4 The System shall provide the Analyst the capability to select the set of waveforms to use in agglomerative hierarchical clustering. (S-1941; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.11.3.2.5 The System shall provide the Analyst the capability to select the threshold value used in hierarchical clustering. (S-1942; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.11.3.2.6 The System shall provide the Analyst the capability to select the agglomerative hierarchical clustering threshold selection algorithm to use in agglomerative hierarchical clustering. (S-1943; Common)
Requirements Trace: SRD-124, SRD-125, SRD-136

3.2.12 User Interface

3.2.12.1 User Interface Processing

3.2.12.1.1 The System shall synchronize the System User's displays based on user actions. (S-1946; Common)
Requirements Trace: SRD-124, SRD-126, SRD-136

3.2.12.1.2 The System shall implement user interfaces according to the User Interface Guidelines. (S-1947; Common)
Requirements Trace: SRD-124, SRD-136, SRD-285

3.2.12.1.3 The System shall provide a command line interface to initiate each application using specific configuration parameters. (S-1952; Common)
Requirements Trace: SRD-286

3.2.12.2 User Interface Support Interfaces

3.2.12.2.1 The System shall provide the System Maintainer the capability to configure the triggering event activities recorded in the Operations Log. (S-1949; Common)
Requirements Trace: SRD-122

3.2.12.2.2 The System shall provide the System Maintainer the capability to authorize a System User to view the Operations Log. (S-1954; Common)
Requirements Trace: SRD-122

3.2.12.2.3 The System shall provide the System Maintainer the capability to configure the criteria for failures, warnings and notifications. (S-1955; Common)
Requirements Trace: SRD-80, SRD-289

3.2.12.3 User Interface User Interfaces

3.2.12.3.1 The System shall provide the System User the capability to enable and disable automatic display synchronization for each display. (S-1957; Common)
Requirements Trace: SRD-126

3.2.12.3.2 The System shall provide an authorized System User the capability to view the Operations Log. (S-1958; Common)
Requirements Trace: SRD-122

3.2.12.3.3 The System shall provide the System User the capability to view on-line help. (S-1959; Common)
Requirements Trace: SRD-285

3.2.12.3.4 The System shall provide the Analyst the capability to enter Operations Log data. (S-1960; Common)
Requirements Trace: SRD-122

3.2.12.3.5 The System shall provide the System User audible and visual cues denoting failures, warnings, and notifications. (S-1961; Common)
Requirements Trace: SRD-80, SRD-228, SRD-289

3.2.12.3.6 The System shall provide the System User the capability to review logged failures, warnings and notifications. (S-1962; Common)
Requirements Trace: SRD-80, SRD-229, SRD-290

3.2.12.3.7 The System shall provide the System User the capability to select which logged failures, warnings and notifications are displayed. (S-1963; Common)
Requirements Trace: SRD-80, SRD-229, SRD-290

3.2.12.3.8 The System shall provide the System User the capability to select the audible notification associated with failures, warning and notifications. (S-1964; Common)
Requirements Trace: SRD-80, SRD-290

3.2.12.3.9 The System shall provide the System User the capability to view the common error log file. (S-1965; Common)
Requirements Trace: SRD-228, SRD-288

3.2.12.3.10 The System shall provide the Researcher the capability to initiate system software applications without dependency on an automated processing pipeline. (S-1950; Common)
Requirements Trace: SRD-270

3.2.12.3.11 The System shall provide the Researcher the capability to use the command line interface. (S-1951; Common)
Requirements Trace: SRD-286

3.2.12.4 User Interface Storage

3.2.12.4.1 The System shall store results from all stages of data processing. (S-1967; Common)
Requirements Trace: SRD-136, SRD-189, SRD-378

3.2.12.4.2 The System shall record selected triggering event activities in the Operations Log. (S-1968; Common)
Requirements Trace: SRD-122

3.2.12.4.3 The System shall store the Operations Log. (S-1969; Common)
Requirements Trace: SRD-122

3.2.12.4.4 The System shall store failures, warnings and notifications. (S-1970; Common)
Requirements Trace: SRD-228

3.2.12.4.5 The System shall store errors in a common log file. (S-1971; Common)
Requirements Trace: SRD-228

3.2.12.4.6 The System shall provide the System User the capability to export the current view to a standard graphic format (e.g. TIFF, JPG or PNG) (S-5703; Common)
Requirements Trace: SRD-452

3.2.13 GIS

The System's data analysis includes evaluating geospatial relationships on a global scale. An interactive, graphical Geographic Information System (GIS) supports analysis by displaying information and performing spatial operations, such as measuring distance from events to geographic features, on maps of the Earth.

Data available in the GIS are:

Event Hypothesis Data: event hypothesis location set, event hypotheses location uncertainty ellipse, and associated signal detections with great circle path indicating azimuth and slowness.

Geographic Data: test sites, station locations, volcanoes, geology, mineral resources, mine locations, Flinn-Engdahl regions, seismicity, seismic faults, geophysical attenuation maps, blockage maps, satellite imagery, topography, political boundaries, population centers, cities, railroads, tunnels, rivers, and roads.

Station Data: station location, associated signal detections, unassociated signal detections.

The System's geographic data can also change over time, e.g. stations are added, political boundaries change. The System tracks change history for the geographic data that the System uses.

The System includes a single GIS tool using OpenGIS standards to display images and features available to the System.

3.2.13.1 GIS Processing

3.2.13.1.1 The System shall generate graphical images of the results of spatial processing of geospatial data. (S-1974; Common)
Requirements Trace: SRD-154

3.2.13.1.2 The System shall generate tabular listings of the results of spatial processing of geospatial data, e.g. event hypothesis data selected by spatial processing with geographic information. (S-1975; Common)
Requirements Trace: SRD-154, SRD-156

3.2.13.1.3 The System shall determine whether an event hypothesis location is within an active geographic region. (S-1976; Common)
Requirements Trace: SRD-98, SRD-144, SRD-152, SRD-156

3.2.13.1.4 The System shall determine whether an event hypothesis uncertainty bound intersects an active geographic region. (S-1977; Common)
Requirements Trace: SRD-98, SRD-152, SRD-156

3.2.13.1.5 The System shall determine whether an event hypothesis location is within an active geographic region for a particular time. (S-1978; Common)
Requirements Trace: SRD-98, SRD-152, SRD-156

3.2.13.1.6 The System shall determine whether an event hypothesis location uncertainty bound intersects an active geographic region for a particular time. (S-1979; Common)
Requirements Trace: SRD-98, SRD-152, SRD-156

3.2.13.2 GIS Support Interfaces

3.2.13.2.1 The System shall provide the System Maintainer the capability to configure a geographic region. (S-1981; Common)
Requirements Trace: SRD-144, SRD-151

3.2.13.2.2 The System shall provide the System Maintainer the capability to configure an active time range of a geographic region. (S-1983; Common)
Requirements Trace: SRD-144, SRD-151

3.2.13.3 GIS User Interfaces

3.2.13.3.1 The System shall provide the Analyst the capability to view event hypothesis data on an interactive map. (S-1985; Common)
Requirements Trace: SRD-124, SRD-136, SRD-149, SRD-150

3.2.13.3.2 The System shall provide the Analyst the capability to view associated and unassociated signal detections on an interactive map. (S-1986; Common)
Requirements Trace: SRD-124, SRD-136, SRD-149, SRD-150

3.2.13.3.3 The System shall provide the Analyst the capability to view station data on an interactive map. (S-1987; Common)
Requirements Trace: SRD-124, SRD-136, SRD-149, SRD-150, SRD-398

3.2.13.3.4 The System shall provide the Analyst the capability to view geographic data on an interactive map. (S-1988; Common)
Requirements Trace: SRD-124, SRD-136, SRD-153

3.2.13.3.5 The System shall provide the Analyst the capability to view active geographic region boundaries on an interactive map. (S-1989; Common)
Requirements Trace: SRD-124, SRD-136, SRD-151

3.2.13.3.6 The System shall provide the Analyst the capability to view inactive geographic region boundaries on an interactive map. (S-5603; Common)
Requirements Trace: SRD-124, SRD-136, SRD-151

3.2.13.3.7 The System shall provide the Analyst the capability to simultaneously view event hypothesis locations and active geographic region boundaries on an interactive map. (S-1990; Common)
Requirements Trace: SRD-124, SRD-136, SRD-151

3.2.13.3.8 The System shall provide the Analyst the capability to simultaneously view event hypothesis locations and inactive geographic region boundaries on an interactive map. (S-5604; Common)
Requirements Trace: SRD-124, SRD-136, SRD-151

3.2.13.3.9 The System shall provide the System User the capability to view on an interactive map whether an event hypothesis location is within active geographic regions. (S-1991; Common)
Requirements Trace: SRD-98, SRD-124, SRD-136, SRD-152

3.2.13.3.10 The System shall provide the Analyst the capability to view on an interactive map whether an event hypothesis location is within an active geographic region for a user

specified time. (S-1992; Common)
Requirements Trace: SRD-98, SRD-124, SRD-136, SRD-152

3.2.13.3.11 The System shall provide the Analyst the capability to view on an interactive map whether an event hypothesis location uncertainty bound intersects an active geographic region for a user specified time. (S-1993; Common)
Requirements Trace: SRD-98, SRD-124, SRD-136, SRD-152

3.2.13.3.12 The System shall provide the Analyst the capability to specify the time associated with whether an event hypothesis location or event hypothesis location uncertainty is within an active geographic region. (S-2597; Common)
Requirements Trace: SRD-98, SRD-124, SRD-136, SRD-152

3.2.13.3.13 The System shall provide the Analyst the capability to search via GIS for the percentage of an event hypothesis uncertainty ellipse that is within an active geographic region. (S-1995; Common)
Requirements Trace: SRD-124, SRD-136, SRD-156

3.2.13.3.14 The System shall provide the Analyst the capability to access geospatial data. (S-1996; Common)
Requirements Trace: SRD-124, SRD-136

3.2.13.3.15 The System shall provide the Analyst the capability to determine the spatial relationships of geospatial data. (S-1998; Common)
Requirements Trace: SRD-124, SRD-136, SRD-156

3.2.13.3.16 The System shall provide the Analyst the capability to view geographic data on a two-dimensional projection and on a three-dimensional virtual globe. (S-5666; Common)
Requirements Trace: SRD-451

3.2.13.3.17 The System shall provide the Analyst the capability to view tabular listings of the results of spatial processing of geospatial data. (S-1999; Common)
Requirements Trace: SRD-154, SRD-156

3.2.13.3.18 The System shall provide the System User the capability to view graphical images of the results of spatial processing of geospatial data. (S-2000; Common)
Requirements Trace: SRD-154, SRD-156

3.2.13.3.19 The System shall provide the Authorized External User the capability to modify previously configured automated event warning/notification targets. (S-5792; IDC only)
Requirements Trace: SRD-220

3.2.13.3.20 The System shall provide the System User the capability to modify previously configured automated event warning/notification targets. (S-5793; IDC only)
Requirements Trace: SRD-220

3.2.13.4 GIS Storage

3.2.13.4.1 The System shall provide the System User the capability to select geographical data on any interactive map (such as events and stations) and export them to a standardized format (e.g. KML/KMZ). (S-5702; Common)
Requirements Trace: SRD-453

3.2.13.4.2 The System shall provide the Analyst the capability to save geospatial data. (S-1997; Common)
Requirements Trace: SRD-136, SRD-154

3.2.14 Event Bulletins and Reports
The System provides event bulletins, GIS displays, performance monitoring statistics, special event reports, escort through chain of command alerts, and executive-level performance reports to internal and external customers.

Event bulletins are one of the primary system reports. Event bulletins contain information on locations of event hypotheses (latitude, longitude, depth, time and magnitude) and their associated signal detections (station, phase label, onset time, and signal amplitude). Event bulletins can be created by any combination of the following criteria: time, location, magnitude, or source type.

3.2.14.1 Event Bulletins and Reports Processing

3.2.14.1.1 The system shall provide a language for requesting station information. (S-5748; Common)
Requirements Trace: SRD-410

3.2.14.1.2 The system shall provide a language for requesting waveform data. (S-5749; Common)
Requirements Trace: SRD-410

3.2.14.1.3 The System shall provide a language for formulating requests for waveform data that provides the specification of attribute values (e.g. time, station, associated with event) of the data to be transferred. (S-5780; Common)
Requirements Trace: SRD-616

3.2.14.1.4 The system shall provide a language for requesting event bulletin data. (S-5750; Common)
Requirements Trace: SRD-410

3.2.14.1.5 The system shall send waveform data to the Authorized External Users based on roles and privileges. (S-5753; IDC only)
Requirements Trace: SRD-616

3.2.14.1.6 The System shall apply user-specified processing to existing data and products to create custom reports. (S-5763; Common)
Requirements Trace: SRD-508

3.2.14.1.7 The System shall distribute all waveform data for an event that satisfies a user-specified set of rules. (S-5779; IDC only)
Requirements Trace: SRD-616

3.2.14.1.8 The System shall apply a digital signature to the reports and waveform data to be distributed. (S-5765; IDC only)
Requirements Trace: SRD-405

3.2.14.1.9 The System shall support at least 1000 Authorized External Users. (S-5766; IDC only)
Requirements Trace: SRD-509

3.2.14.1.10 The System shall support each Authorized External User requesting up to 4GB of data per day. (S-5767; IDC only)
Requirements Trace: SRD-509

3.2.14.1.11 The System shall support at least 30000 requests for data and products per day. (S-5768; IDC only)
Requirements Trace: SRD-510

3.2.14.1.12 The System shall provide a prioritization scheme of queued requests such that reports provided interactively are served faster than via email. (S-5769; Common)
Requirements Trace: SRD-511

3.2.14.1.13 The System shall respond to Authorized External User requests for waveform data and reports within the timeframes specified in the IDC Operations manual. (S-5770; IDC only)
Requirements Trace: SRD-511

3.2.14.1.14 The System shall convert event bulletin data to the CSS 3.0 format. (S-1244; Common)
Requirements Trace: SRD-505

3.2.14.1.15 The System shall convert event bulletins to the QuakeML format (S-5668; IDC only)
Requirements Trace: SRD-505

3.2.14.1.16 The System shall provide requested reports via email. (S-5699; Common)
Requirements Trace: SRD-401, SRD-505

3.2.14.1.17 The System shall provide requested reports via a secure website. (S-5701; Common)
Requirements Trace: SRD-505

3.2.14.1.18 The System shall provide a secure web services interface to reports and waveform data. (S-5891; Common)
Requirements Trace: SRD-506

3.2.14.1.19 The System shall distribute reports and waveform data as specified in the IDC Formats and Protocols document. (S-5931; Common)
Requirements Trace: SRD-485, SRD-507

3.2.14.2 Event Bulletins and Reports Support Interfaces

3.2.14.2.1 The System shall provide the System Maintainer the capability to configure by station which Authorized External Users can be sent waveform data. (S-5758; IDC only)
Requirements Trace: SRD-160, SRD-616

3.2.14.2.2 The System shall provide the System User the capability to configure user-specified processing of data and products to create custom reports. (S-5764; Common)
Requirements Trace: SRD-508

3.2.14.2.3 The System shall provide the System Maintainer the capability to configure a maximum data size request limit threshold per type of report. (S-5771; IDC only)
Requirements Trace: SRD-511

3.2.14.3 Event Bulletins and Reports User Interfaces

3.2.14.3.1 The System shall provide the Analyst the capability to access third-party event bulletins in the same way they access event bulletins produced by the System. (S-2019; Common)
Requirements Trace: SRD-124, SRD-136, SRD-163

3.2.14.3.2 The System shall provide the Analyst the capability to create event bulletins after any processing stage (automated or interactive) that forms event hypotheses. (S-2020; Common)
Requirements Trace: SRD-165

3.2.14.3.3 The System shall provide the External Release Authority the capability to edit event bulletins before release. (S-2021; Common)
Requirements Trace: SRD-165

3.2.14.3.4 The System shall provide the System User the capability to print reports. (S-2022; Common)
Requirements Trace: SRD-165

3.2.14.3.5 The System shall provide the System User the capability to access reports based on their roles and privileges. (S-2003; Common)
Requirements Trace: SRD-160, SRD-163

3.2.14.3.6 The System shall provide the Authorized External User the capability to access reports based on their roles and privileges. (S-2006; Common)
Requirements Trace: SRD-160, SRD-163, SRD-482

3.2.14.3.7 The System shall provide the Authorized External User the capability to access reports via a web server. (S-2007; Common)
Requirements Trace: SRD-163

3.2.14.3.8 The System shall provide the Authorized External User the capability to view reports. (S-5892; Common)
Requirements Trace: SRD-483

3.2.14.3.9 The System shall provide the System User the capability to view reports. (S-5893; Common)
Requirements Trace: SRD-483

3.2.14.3.10 The System shall provide the Authorized External User the capability to request reports via email. (S-5698; Common)
Requirements Trace: SRD-401, SRD-505

3.2.14.3.11 The System shall provide the Authorized External User the capability to request reports via a secure website. (S-5700; Common)
Requirements Trace: SRD-505

3.2.14.3.12 The System shall provide the Authorized External User the capability to request waveform data for an event. (S-5751; IDC only)
Requirements Trace: SRD-616

3.2.14.3.13 The System shall provide the Authorized External User the capability to save reports. (S-2010; Common)
Requirements Trace: SRD-483

3.2.14.3.14 The System shall provide the Authorized External User the capability to export reports. (S-2011; Common)
Requirements Trace: SRD-483

3.2.14.3.15 The System shall provide the Authorized External User the capability to access third-party reports. (S-2012; Common)
Requirements Trace: SRD-163

3.2.14.3.16 The System shall provide the System User the capability to access reports via a GIS. (S-2013; Common)
Requirements Trace: SRD-484

3.2.14.3.17 The System shall provide the Authorized External User the capability to access reports via a GIS. (S-5894; Common)
Requirements Trace: SRD-484

3.2.14.3.18 The System shall provide the System User the capability to access reports via tabular format. (S-2014; Common)
Requirements Trace: SRD-483

3.2.14.3.19 The System shall provide the External Release Authority the capability to select the set of events available for release to Authorized External Users. (S-2015; Common)
Requirements Trace: SRD-160

3.2.14.3.20 The System shall provide the Authorized External User the capability to create an event bulletin from the set of released events. (S-2016; Common)
Requirements Trace: SRD-160

3.2.14.3.21 The System shall provide the System User the capability to create event bulletins based on any combination of geographic region, time interval, depth, magnitude interval, source type, stations, latitude, and longitude. (S-2017; Common)
Requirements Trace: SRD-165

3.2.14.3.22 The System shall provide the Authorized External User the capability to request event bulletins in QuakeML format. (S-5840; IDC only)
Requirements Trace: SRD-611

3.2.14.3.23 The System shall provide the Authorized External User the capability to subscribe to reports and waveform data. (S-5930; Common)
Requirements Trace: SRD-507

3.2.14.3.26 The System shall provide the Authorized External User the capability to request alphanumeric data in the CSS 3.0 format. (S-1249; Common)
Requirements Trace: SRD-505, SRD-616

3.2.14.3.27 The System shall provide the System User the capability to compare two event bulletins for signal detection characteristics of two event hypotheses. (S-2111; Common)
Requirements Trace: SRD-247

3.2.14.3.28 The System shall provide the System User the capability to compare two event bulletins for the characteristics of two event hypotheses. (S-2112; Common)
Requirements Trace: SRD-247

3.2.14.3.29 The System shall provide the System User the capability to perform statistical comparisons between two event bulletins. (S-2113; Common)
Requirements Trace: SRD-247

3.2.14.4 Event Bulletins and Reports Storage

3.2.14.4.1 The System shall store third-party bulletin data in the System data format. (S-2024; Common)
Requirements Trace: SRD-163, SRD-174

3.2.15 Data Management
The System stores waveforms, configuration parameters, and processing results.

3.2.15.1 System Configuration

3.2.15.1.1 System Configuration Processing

3.2.15.1.1.1 The System shall maintain a history of the system configurations. (S-5736; Common)
Requirements Trace: SRD-466

3.2.15.1.2 System Configuration Support Interfaces

3.2.15.1.2.1 The System shall provide the System Maintainer the capability to restore the configuration that was valid at a specific time in the past. (S-5737; Common)
Requirements Trace: SRD-466

3.2.15.2 Common Object Interface

3.2.15.2.1 Common Object Interface Processing

3.2.15.2.1.1 The System shall use a common object interface (data model and methods) for data. (S-2028; Common)
Requirements Trace: SRD-268

3.2.15.2.2 Common Object Interface User Interfaces

3.2.15.2.2.1 The System shall provide the Researcher the capability to access data through a common object interface. (S-2030; Common)
Requirements Trace: SRD-268

3.2.15.2.2.2 The System shall provide the Researcher the capability to access the database through an ANSI/ISO standard SQL interface. (S-2031; Common)
Requirements Trace: SRD-301

3.2.15.3 Processing Parameters

The System provides an infrastructure linking processing parameter and recipe information with each event hypothesis, event hypothesis location, and signal detection created and stored by the System. Automatic and interactive processing applications use this infrastructure to set default values for processing parameters and recipes, and to track changes in processing parameters and recipes.

This infrastructure insures processing results can be recreated from one processing stage to the next (e.g., for both interactive and automatic fk analysis, use the same stations (spatial sampling), frequency-band (frequency sampling), lead and lag (temporal sampling), and Waveform QC Masks). Processing parameters are dynamic values preserved at each processing stage rather than static values used by all processing stages. When default values can be overridden when computing a processing result, the overridden values are linked to that processing result.

Defining/non-defining state behavior refers to how measurements are used in an event processing function. A measurement that is associated to a particular calculation is considered "defining" if it is enabled as input to that calculation; otherwise it is considered "non-defining"

for that calculation. System configuration and precedence rules determine the default defining state by geographic region, time of year, time of day, network, station, channel, phase, observable type, and processing function. System processing may adjust the defining state based on data quality and measurement residual. Analysts may adjust the defining state as desired during interactive processing.

3.2.15.3.1 Processing Parameters Processing

3.2.15.3.1.1 The System shall use configured default defining/non-defining state settings and precedence rules to determine the initial defining/non-defining state for each parameter. (S-2036; Common)
Requirements Trace: SRD-110, SRD-291

3.2.15.3.2 Processing Parameters Support Interfaces

3.2.15.3.2.1 The System shall provide the System Maintainer the capability to configure the default defining/non-defining state by geographic region, time of year, network, station, channel, phase, parameter type, and processing function. (S-2038; Common)
Requirements Trace: SRD-110, SRD-291

3.2.15.3.3 Processing Parameters Storage

3.2.15.3.3.1 The System shall store automatic and interactive processing parameters in the database. (S-2042; Common)
Requirements Trace: SRD-189

3.2.15.3.3.2 The System shall store the relation of processing results to processing parameters in the database. (S-2044; Common)
Requirements Trace: SRD-189

3.2.15.4 Database Backup

3.2.15.4.1 Database Backup Processing

3.2.15.4.1.1 The System shall backup all information necessary to reconstruct the entire system including software and data. (S-2048; Common)
Requirements Trace: SRD-168

3.2.15.4.2 Database Backup Support Interfaces

3.2.15.4.2.1 The System shall provide the System Maintainer the capability to recover the entire system including software and data. (S-2049; Common)
Requirements Trace: SRD-168

3.2.15.4.3 Database Backup Storage

3.2.15.4.3.1 The System shall store backups off-line. (S-2056; Common)
Requirements Trace: SRD-168

3.2.15.4.3.2 The System shall store backups off-site. (S-2057; Common)
Requirements Trace: SRD-168

3.2.15.5 Database Synchronization

3.2.15.5.1 Database Synchronization Processing

3.2.15.5.1.1 The System shall synchronize bulletin data from the data acquisition system of the Primary to the Data Acquisition Partition of the Backup in near real-time. (S-2060; Common)
Requirements Trace: SRD-472

3.2.15.5.1.2 The System shall synchronize databases from the Data Processing Partition of the Primary to the Data Processing Partition of the Backup in near real-time. (S-2061; Common)
Requirements Trace: SRD-472

3.2.15.5.1.3 The System shall synchronize waveform data from the Data Acquisition Partition of the Primary to the Data Acquisition Partition of the Backup in near real-time. (S-2062; Common)
Requirements Trace: SRD-472

3.2.15.5.1.4 The System shall synchronize waveform data from the Data Processing Partition of the Primary to the Data Processing Partition of the Backup in near real-time. (S-2063; Common)
Requirements Trace: SRD-472

3.2.15.5.1.5 The System shall confirm 100% of data transfer integrity prior to deleting data from source storage. (S-2067; Common)
Requirements Trace: SRD-187

3.2.15.5.1.6 The System Data Acquisition Partition shall import data from high-density media. (S-2068; Common)
Requirements Trace: SRD-184, SRD-300

3.2.15.5.1.7 The System Data Processing Partition shall import data from high-density media. (S-2069; Common)
Requirements Trace: SRD-184, SRD-300

3.2.15.5.2 Database Synchronization Support Interfaces

3.2.15.5.2.1 The System shall provide the System Maintainer the capability for importing data. (S-2072; Common)
Requirements Trace: SRD-300

3.2.15.5.3 Database Synchronization User Interfaces

3.2.15.5.3.1 The System shall provide the System User the capability to export selected data. (S-2071; Common)
Requirements Trace: SRD-300

3.2.16 Performance Monitoring

Performance Monitoring involves the calculation, display and archiving of key indicators for each component of the System data processing system. The key indicators are statistically derived values providing empirical validation for theoretical forecast models and are the inputs to system capability reporting.

Key indicator archiving has a threefold mission of maintaining appropriate resolution, providing a baseline to gauge the impact of changes to the System, and establishing compatibility with forecast models.

Users view Performance Monitoring key indicators, perform trend analysis, and receive automated notifications when key indicators reach critical status.

3.2.16.1 Mission Performance Monitoring

3.2.16.1.1 Mission Performance Monitoring Processing

3.2.16.1.1.1 The System shall compute station ambient noise probability density functions. (S-2076; Common)
Requirements Trace: SRD-238

3.2.16.1.1.2 The System shall compute maximum likelihood empirical station magnitude detection thresholds by geographic region based on the historic event bulletin. (S-2077; Common)
Requirements Trace: SRD-242

3.2.16.1.1.3 The System shall compute station processing statistics. (S-2078; Common)
Requirements Trace: SRD-240

3.2.16.1.1.4 The System shall compute uncertainties associated with empirical station magnitude detection thresholds for a geographic region. (S-2079; Common)
Requirements Trace: SRD-242

3.2.16.1.1.5 The System shall estimate a station's empirical magnitude detection threshold for aseismic regions using historic event hypotheses within a configurable distance range from that station. (S-2080; Common)
Requirements Trace: SRD-242

3.2.16.1.1.6 The System shall calculate event hypothesis statistics for a geographic region and time period. (S-2081; Common)
Requirements Trace: SRD-243

3.2.16.1.2 Mission Performance Monitoring User Interfaces

3.2.16.1.2.1 The System shall provide the Performance Monitor the capability to display real-time estimates of event detection probability at a specified magnitude based on empirical and model based parameters. (S-2091; Common)
Requirements Trace: SRD-244

3.2.16.1.2.2 The System shall provide the Performance Monitor the capability to display real-time estimates of event location uncertainty based on empirical and model based parameters. (S-2092; Common)
Requirements Trace: SRD-244

3.2.16.1.2.3 The System shall provide the Performance Monitor the capability to select thresholds for station processing statistics. (S-2084; Common)
Requirements Trace: SRD-240

3.2.16.1.2.4 The System shall provide the Performance Monitor the capability to select the time interval used for computing station processing statistics. (S-2085; Common)
Requirements Trace: SRD-240

3.2.16.1.2.5 The System shall provide the Performance Monitor the capability to select the computation of station processing statistics based on geographic region. (S-2086; Common)
Requirements Trace: SRD-240

3.2.16.1.2.6 The System shall provide the Performance Monitor the capability to select the geographic regions the System uses to compute empirical station magnitude detection thresholds. (S-2087; Common)
Requirements Trace: SRD-242

3.2.16.1.2.7 The System shall provide the Performance Monitor the capability to select by geographic region the distance range the System uses to compute the station magnitude detection thresholds for aseismic regions. (S-2088; Common)
Requirements Trace: SRD-242

3.2.16.1.2.8 The System shall provide the Performance Monitor the capability to select the temporal range used to compute the station magnitude detection threshold for a specific geographic region (S-2089; Common)
Requirements Trace: SRD-242

3.2.16.1.2.9 The System shall provide the Performance Monitor the capability to select the models to be used for network capability simulation. (S-2094; Common)
Requirements Trace: SRD-244

3.2.16.1.2.10 The System shall provide the Performance Monitor the capability to select the parameters to be used for network capability simulation. (S-2095; Common)
Requirements Trace: SRD-244

3.2.16.1.2.11 The System shall provide the Performance Monitor the capability to select the network configuration to be used for network capability simulation. (S-2096; Common)
Requirements Trace: SRD-244

3.2.16.1.2.12 The System shall provide the Performance Monitor the capability to display tables of station processing statistics. (S-2105; Common)
Requirements Trace: SRD-240

3.2.16.1.2.13 The System shall provide the Performance Monitor the capability to graphically view station processing statistics. (S-2106; Common)
Requirements Trace: SRD-240

3.2.16.1.2.14 The System shall provide the Performance Monitor the capability to simultaneously display station processing statistics, the processing parameters used to compute those statistics, and the dates and times of changes to those processing parameters. (S-2107; Common)
Requirements Trace: SRD-240

3.2.16.1.2.15 The System shall provide the Performance Monitor the capability to compare a current station statistic with other (up to 5) selectable time periods concurrently. (S-2109; Common)
Requirements Trace: SRD-241

3.2.16.1.2.16 The System shall provide the Performance Monitor the capability to view station magnitude detection thresholds computed for a geographic region. (S-2110; Common)
Requirements Trace: SRD-124, SRD-136, SRD-242

3.2.16.1.2.17 The System shall provide the Performance Monitor the capability to view event hypothesis statistics for a user specified geographic region for a specified time period. (S-2114; Common)
Requirements Trace: SRD-243

3.2.16.1.2.18 The System shall notify the Performance Monitor when a station processing statistic varies outside of a configurable range. (S-2115; Common)
Requirements Trace: SRD-240

3.2.16.1.3 Mission Performance Monitoring Storage

3.2.16.1.3.1 The System shall store ambient noise probability density functions. (S-2117; Common)
Requirements Trace: SRD-189

3.2.16.1.3.2 The System shall store station processing statistics. (S-2118; Common)
Requirements Trace: SRD-240

3.2.16.1.3.3 The System shall store station magnitude detection thresholds for a geographic region. (S-2119; Common)
Requirements Trace: SRD-189, SRD-242

3.2.16.1.3.4 The System shall store uncertainties associated with station magnitude detection thresholds for a geographic region. (S-2120; Common)
Requirements Trace: SRD-242

3.2.16.2 Station State-of-Health
Station health is a combination of key indicators that include the ability to identify which components of a station are functioning, the reason for malfunctioning components, and the timing of routine/emergency maintenance.

Network health is a combination of key indicators monitoring data acquisition from stations. It is used to prioritize station maintenance. Key indicators are:

- Latency of each channel compared to historic average latency
- Channel calibration values vs. time for identifying significant changes

3.2.16.2.1 Station State-of-Health Processing

3.2.16.2.1.1 The System shall update system State-of-Health displays with newly acquired data within 1 minute of acquisition. (S-2123; Common)
Requirements Trace: SRD-130

3.2.16.2.1.2 The System shall compute latency measurements of waveform data intervals between station waveform data recording and waveform data arrival at the System. (S-2124; Common)
Requirements Trace: SRD-232

3.2.16.2.2 Station State-of-Health Support Interfaces

3.2.16.2.2.1 The System shall provide the System Maintainer the capability to configure the parameters the System uses to calculate station ambient noise probability density functions. (S-2083; Common)
Requirements Trace: SRD-238

3.2.16.2.3 Station State-of-Health User Interfaces

3.2.16.2.3.1 The System shall provide the System User the capability to view all station State-of Health status values. (S-2127; Common)
Requirements Trace: SRD-120

3.2.16.2.3.2 The System shall provide the System User the capability to view all network State-of Health status values. (S-2128; Common)
Requirements Trace: SRD-120

3.2.16.2.3.3 The System shall provide the Analyst the capability to view waveform data availability at a user specified time. (S-2129; Common)
Requirements Trace: SRD-124, SRD-136, SRD-233

3.2.16.2.3.4 The System shall provide the System User the capability to view latency measurements for waveform data intervals. (S-2130; Common)
Requirements Trace: SRD-124, SRD-136, SRD-232

3.2.16.2.3.5 The System shall provide the System User the capability to view station ambient noise probability density functions. (S-2097; Common)
Requirements Trace: SRD-238

3.2.16.2.3.6 The System shall provide the System User the capability to compare current station ambient noise probability density functions with the station's ambient noise probability density functions from other (up to 5) selectable time periods concurrently. (S-2098; Common)
Requirements Trace: SRD-239

3.2.16.2.3.7 The System shall provide the System User the capability to compare current station spectrograms with the station's spectrograms from other (up to 5) selectable time periods concurrently. (S-5723; Common)
Requirements Trace: SRD-239

3.2.16.2.3.8 The System shall provide the System User the capability to compare current station power spectral density with the station's power spectral density from other (up to 5) selectable time periods concurrently. (S-5724; Common)
Requirements Trace: SRD-239

3.2.16.2.3.9 The System shall provide the System User the capability to select the parameters the System uses to calculate station ambient noise probability density functions. (S-5718; Common)
Requirements Trace: SRD-238

3.2.16.2.4 Station State-of-Health Storage

3.2.16.2.4.1 The System shall store raw waveform data availabilities for specific points in the processing history. (S-2134; Common)
Requirements Trace: SRD-172, SRD-189, SRD-233

3.2.16.2.4.2 The System shall store latency measurements for waveform data intervals. (S-2135; Common)
Requirements Trace: SRD-172, SRD-232, SRD-233

3.2.16.3 System Performance Monitoring

General system State-of-Health captures many system characteristics impacting performance and reliability. These values are sampled, captured, and reported using operating system tools.

System State-of-Health status values are:

- Memory usage
- Uptime

- Network interface average receiving rate
- Network interface peak receiving rate
- Network interface average transmitting rate
- Network interface peak transmitting rate
- Available disk space
- Used disk space
- Compute node response state
- Application program run status
- Application program load times
- Orphaned application processes
- Current level of backlogged waveform data waiting for pipeline processing

Storage health provides key indicators for determining stored data integrity and disk consumption rate. Key indicators are:

- Critical storage limit, load usage failure level, and usage rates
- Daily number of new core files per application per day

3.2.16.3.1 System Performance Monitoring Processing

3.2.16.3.1.1 The System shall monitor, detect, log, and characterize software and hardware failures of all systems and networks. (S-2138; Common)
Requirements Trace: SRD-227

3.2.16.3.1.2 The System shall report failures, warnings and notifications using a common messaging infrastructure. (S-2139; Common)
Requirements Trace: SRD-228, SRD-289

3.2.16.3.1.3 The System shall measure Analyst Application usage. (S-2140; Common)
Requirements Trace: SRD-249

3.2.16.3.2 System Performance Monitoring Support Interfaces

3.2.16.3.2.1 The System shall provide the System Maintainer the capability to view Analyst Application usage statistics. (S-2146; Common)
Requirements Trace: SRD-249

3.2.16.3.3 System Performance Monitoring User Interfaces

3.2.16.3.3.1 The System shall provide the System User the capability to view the state of all system processes in near real time. (S-2143; Common)
Requirements Trace: SRD-226, SRD-288

3.2.16.3.3.2 The System shall provide the System User the capability to view all system State-of-Health status values. (S-2144; Common)
Requirements Trace: SRD-120, SRD-225, SRD-226

3.2.16.3.3.3 The System shall provide the System User the capability to monitor the State-of-Health of critical hardware components of the Primary from the Backup. (S-2147; Common)
Requirements Trace: SRD-225, SRD-360

3.2.16.3.3.4 The System shall provide the System User the capability to monitor the State-of-Health of critical hardware components of the Primary from the Primary. (S-2148; Common)
Requirements Trace: SRD-225

3.2.16.3.3.5 The System shall provide the System User the capability to monitor the State-of-Health of critical software components of the Primary from the Backup. (S-2149; Common)
Requirements Trace: SRD-226, SRD-360

3.2.16.3.3.6 The System shall provide the System User the capability to monitor the State-of-Health of critical software components of the Primary from the Primary. (S-2150; Common)
Requirements Trace: SRD-226

3.2.16.3.3.7 The System shall provide the System User the capability to monitor the State-of-Health of critical hardware components of the Backup from the Primary. (S-2151; Common)
Requirements Trace: SRD-225, SRD-360

3.2.16.3.3.8 The System shall provide the System User the capability to monitor the State-of-Health of critical hardware components of the Backup from the Backup. (S-2152; Common)
Requirements Trace: SRD-225

3.2.16.3.3.9 The System shall provide the System User the capability to monitor the State-of-Health of critical software components of the Backup from the Primary. (S-2153; Common)
Requirements Trace: SRD-226, SRD-360

3.2.16.3.3.10 The System shall provide the System User the capability to monitor the State-of-Health of critical software components of the Backup from the Backup. (S-2154; Common)
Requirements Trace: SRD-226

3.2.16.3.4 System Performance Monitoring Storage

3.2.16.3.4.1 The System shall store all available system State-of-Health status values. (S-2156; Common)
Requirements Trace: SRD-120, SRD-225

3.2.16.3.4.2 The System shall store Analyst Application usage measurements. (S-2157; Common)
Requirements Trace: SRD-189, SRD-249

3.2.16.4 Geophysical Performance Tuning

The System will provide a set of software tools to support tuning and evaluation of geophysical performance. These tools will allow a user to rerun decision algorithms (including detection and association) with a range of values for a single input parameter. All other parameters will be fixed to view the influence of the single parameter on the decision.

In addition, system will allow the user to export time-series signals generated during signal processing. Time-series signals are exported to SAC (Seismic Analysis Code) file formats. Signal processing may contain several transformations (including filtering, beaming, STA/LTA, etc…). The System should allow the user to export after each transformation.

3.2.16.4.1 Geophysical Performance Tuning User Interfaces

3.2.16.4.1.1 The System shall provide the Researcher the capability to store time-series signals generated by each transformation applied during system signal processing for evaluation by third-party tools. (S-2159; Common)
Requirements Trace: SRD-245

3.2.16.4.1.2 The System shall provide the Researcher the capability to view a detection algorithm's change in performance over a range of values for parameters of the respective detection algorithm. (S-2160; Common)
Requirements Trace: SRD-245

3.2.16.4.1.3 The System shall provide the Researcher the capability to view change in performance for event hypothesis formation over a range of values for parameters of the respective event hypothesis formation algorithm. (S-2161; Common)
Requirements Trace: SRD-245

3.2.17 Timeliness and System Loading

System performance refers to data processing timeliness and system loading requirements. The volume of data and the number of events processed by the existing systems have grown dramatically in the past decade.

Projecting future growth, the interactive data processing software needs to be designed with a possible 2,000 events per day.

The design of interactive applications should take into account the current loads on the users as well as changes in the future to ensure the tools are capable of supporting the users in both

normal and swarm conditions. These requirements impact not only the memory and CPU loads of the tools but also the presentation of the data to the users. This may include getting data to the user quickly, providing the "next step" to the user automatically, or ensuring communication between multiple windows/applications in both the current user's session as well as other users.

3.2.17.1 Timeliness and System Loading Processing

3.2.17.1.1 The System shall access requested waveform data within one (1) minute of receipt by the Data Processing Partition. (S-2164; Common)
Requirements Trace: SRD-261

3.2.17.1.2 The System shall generate virtual origin beams for a specified time interval (less than or equal to 4 hours) and location in less than five (5) minutes. (S-2165; Common)
Requirements Trace: SRD-262

3.2.17.1.3 The System shall automatically process late-arriving waveform data within one (1) minute of receipt by the Data Processing Partition. (S-2166; Common)
Requirements Trace: SRD-265

3.2.17.1.4 The System shall read a 6 hour or less time block of 40Hz waveform data within the Operational Processing Time Period with a maximum 5 second latency. (Goal: 1 second.) (S-2169; Common)
Requirements Trace: SRD-185

3.2.17.1.5 The System shall read a 6 hour or less time block of processing results within the Operational Processing Time Period with a maximum 5 second latency. (Goal: 1 second.) (S-5708; Common)
Requirements Trace: SRD-185

3.2.17.1.6 The System shall write a 6 hour or less time block of 40Hz waveform data within the Operational Processing Time Period with a maximum 5 second latency. (Goal: 1 second.) (S-2167; Common)
Requirements Trace: SRD-185

3.2.17.1.7 The System shall read a 6 hour or less time block of processing results outside the Operational Processing Time Period with a maximum 10 second latency. (Goal: 2 seconds.) (S-5712; Common)
Requirements Trace: SRD-186

3.2.17.1.8 The System shall write a 6 hour or less time block of processing results within the Operational Processing Time Period with a maximum 5 second latency. (Goal: 1 second.) (S-5709; Common)
Requirements Trace: SRD-185

3.2.17.1.9 The System shall write a 6 hour or less time block of processing results from outside the Operational Processing Time Period with a maximum 10 second latency. (Goal: 2 seconds.) (S-5713; Common)
Requirements Trace: SRD-186

3.2.17.1.10 The System shall read a 6 hour or less time block of 40Hz waveform data outside the Operational Processing Time Period with a maximum 10 second latency. (Goal: 2 seconds.) (S-2168; Common)
Requirements Trace: SRD-186

3.2.17.1.11 The System shall write a 6 hour or less time block of 40Hz waveform data from outside the Operational Processing Time Period with a maximum 10 second latency. (Goal: 2 seconds.) (S-2170; Common)
Requirements Trace: SRD-186

3.2.17.1.12 The System shall prioritize the processing of real time data over the processing of late arriving data. (S-2171; Common)
Requirements Trace: SRD-277

3.2.17.1.13 The System shall automatically initiate data processing within 5 minutes of data acquisition on the Data Processing Partition. (S-2172; Common)
Requirements Trace: SRD-255

3.2.17.1.14 The System shall generate automated measurements in less than three (3) seconds for an event hypothesis with up to 100 associated signal detections. (S-2174; Common)
Requirements Trace: SRD-263

3.2.17.1.15 The System shall process up to 2000 seismic event hypotheses per day without disruption of the data processing partition. (S-2175; Common)
Requirements Trace: SRD-253, SRD-280

3.2.17.1.16 The System shall provide a team of 10 concurrent analysts the capability to process up to 2000 seismic event hypotheses per 24 hour day. (S-2176; Common)
Requirements Trace: SRD-136, SRD-253

3.2.17.1.17 The System shall produce an automated event bulletin in near real-time during normal conditions without disrupting operations. (S-2177; Common)
Requirements Trace: SRD-255

3.2.17.1.18 The System shall produce an automated event bulletin in near real-time during swarm conditions without disrupting operations. (S-2178; Common)
Requirements Trace: SRD-255

3.2.18 Security

3.2.18.1 Security Processing
Note: The CTBTO "Single Sign On" is currently implemented using Oracle Access Management.

3.2.18.1.1 The System shall provide user identification and authentication for access control. (S-2183; Common)
Requirements Trace: SRD-319

3.2.18.1.2 The System shall provide separate access control for users accessing the system internally and externally. (S-5697; Common)
Requirements Trace: SRD-160

3.2.18.1.3 The System shall uniquely record the users logged on to the System. (S-2184; Common)
Requirements Trace: SRD-324

3.2.18.1.4 The System shall log all user login attempts and logouts. (S-2186; Common)
Requirements Trace: SRD-316

3.2.18.1.5 The System shall encrypt user passwords when stored on the System. (S-2187; Common)
Requirements Trace: SRD-316

3.2.18.1.6 The System shall lock the user account upon a configurable number of successive authentication failures involving an incorrect password. (S-2188; Common)
Requirements Trace: SRD-316

3.2.18.1.7 The System shall reject authentication requests involving passwords over a configurable number of days old. (S-2189; Common)
Requirements Trace: SRD-316

3.2.18.1.8 The System shall log all requests to initiate and terminate system processing. (S-2190; Common)
Requirements Trace: SRD-318

3.2.18.1.9 The System shall reject all processing requests from unauthorized Users. (S-2191; Common)
Requirements Trace: SRD-317, SRD-318

3.2.18.1.10 The System shall prevent unauthorized access. (S-2192; Common)
Requirements Trace: SRD-320

3.2.18.1.11 The System shall record the date and time of each auditable security event. (S-2196; Common)
Requirements Trace: SRD-325

3.2.18.1.12 The System shall record the type of each auditable security event. (S-2197; Common)
Requirements Trace: SRD-325

3.2.18.1.13 The System shall record the success or failure of each auditable security event. (S-2198; Common)
Requirements Trace: SRD-325

3.2.18.1.14 The System shall record the name of the object that was introduced, accessed, modified or deleted as part of each auditable security event. (S-2199; Common)
Requirements Trace: SRD-325

3.2.18.1.15 The System shall monitor security logs (i.e., networks, databases, servers, applications) and notify the System Maintainer of security events. (S-2208; Common)
Requirements Trace: SRD-324

3.2.18.1.16 The System shall provide user identification and authentication through the CTBTO "single sign on". (S-5687; IDC only)
Requirements Trace: SRD-483

3.2.18.2 Security Support Interfaces

3.2.18.2.1 The System shall provide the System Maintainer the capability to review security logs (i.e., networks, database, servers, and applications). (S-2204; Common)
Requirements Trace: SRD-324

3.2.18.2.2 The System shall provide the System Maintainer the capability to display the authorized users and when each last accessed the System. (S-2205; Common)
Requirements Trace: SRD-316

3.2.18.2.3 The System shall provide the System Maintainer the capability to lock or unlock a user account. (S-2206; Common)
Requirements Trace: SRD-316

3.2.18.2.4 The System shall provide the System Maintainer the capability to grant a temporary user password. (S-2207; Common)
Requirements Trace: SRD-316

3.2.18.2.5 The System shall provide the System Maintainer the capability to add and delete user accounts. (S-2185; Common)
Requirements Trace: SRD-316

3.2.18.2.6 The System shall provide the System Maintainer the capability to configure access control. (S-5695; Common)
Requirements Trace: SRD-160, SRD-483

3.2.18.2.7 The System shall provide the System Maintainer the capability to configure the access control for a user based on whether that user is accessing the system internally or externally. (S-5696; Common)
Requirements Trace: SRD-160

3.2.18.3 Security User Interfaces

3.2.18.3.1 The System shall provide the System User the capability to access the System using their CTBTO "single sign on" credentials. (S-5686; IDC only)
Requirements Trace: SRD-483

3.2.19 Testing

3.2.19.1 Testing Processing

3.2.19.1.1 The Development Subsystem shall replay waveform data using the data's original acquisition sequencing and latencies. (S-2214; Common)
Requirements Trace: SRD-299, SRD-414

3.2.19.1.2 The Development Subsystem shall replay waveform data faster than real time. (S-5729; Common)
Requirements Trace: SRD-414

3.2.19.2 Testing User Interfaces

3.2.19.2.1 The System shall provide the Developer the capability to synchronize injection of waveform replay data stemming from multiple data sources. (S-2215; Common)
Requirements Trace: SRD-299

3.2.19.2.2 The System shall provide the Developer the capability to capture waveform raw data and acquisition times for the purpose of replay. (S-2213; Common)
Requirements Trace: SRD-299, SRD-414

3.2.19.2.3 The Development Subsystem shall provide the Developer the capability to select the waveform data for replay. (S-5728; Common)
Requirements Trace: SRD-414

3.2.19.2.4 The Development Subsystem shall provide the Developer the capability to select the waveform data replay data rate. (S-5730; Common)
Requirements Trace: SRD-414

3.2.20 External Interfaces

3.2.20.1 External Interfaces Processing

3.2.20.1.1 The System shall provide authorized systems read-only access to database contents. (S-2238; Common)
Requirements Trace: SRD-297

3.2.20.1.2 The System shall provide a secure web services interface for System and processing SOH data. (S-5791; Common)
Requirements Trace: SRD-493

3.2.20.2 External Interfaces User Interfaces

3.2.20.2.1 The System shall provide the System User the capability to view station calibration results. (S-5674; IDC only)
Requirements Trace: SRD-493

3.2.20.2.2 The System shall provide the System Controller the capability to securely issue commands to start station calibration for seismic, hydroacoustic and infrasound stations of the IMS network following IDC Formats and Protocols. (S-5586; IDC only)
Requirements Trace: SRD-493

3.2.20.2.3 The System shall provide the System Controller the capability to securely issue commands to confirm that a station has been calibrated for seismic, hydroacoustic and infrasound stations in the IMS network following IDC Formats and Protocols. (S-5587; IDC only)
Requirements Trace: SRD-493

3.2.20.2.4 The System shall provide the System Controller the capability to securely issue commands to request calibration results from seismic, hydroacoustic and infrasound stations of the IMS network following IDC Formats and Protocols. (S-5588; IDC only)
Requirements Trace: SRD-493

3.2.20.2.5 The System shall provide the System Controller the capability to securely issue commands to generate a new keypair for seismic, hydroacoustic and infrasound stations of the IMS network following IDC Formats and Protocols. (S-5589; IDC only)
Requirements Trace: SRD-493

3.2.20.2.6 The System shall provide the System Controller the capability to securely issue commands to start using the new keypair for seismic, hydroacoustic and infrasound stations of the IMS network following IDC Formats and Protocols. (S-5590; IDC only)
Requirements Trace: SRD-493

3.2.20.2.7 The System shall provide the System Controller the capability to securely issue commands to update a new Certificate Revocation List (CRL) from seismic, hydroacoustic and infrasound stations of the IMS network following IDC Formats and Protocols. (S-5591; IDC only)
Requirements Trace: SRD-493

3.2.20.3 External Interfaces Storage

3.2.20.3.1 The System shall store station calibration results. (S-5670; IDC only)
Requirements Trace: SRD-493

3.2.21 System Startup and Shutdown
The System has both a planned and an urgent unplanned shutdown. Both planned and urgent unplanned shutdowns are initiated by the user. Planned shutdowns must complete within 30 minutes and gracefully shutdown all software (including transfer of the pipeline) and hardware with no loss of data and no damage to the hardware. An urgent unplanned shutdown must complete within 15 minutes and must shutdown all hardware with no damage. For example, the System should undergo an urgent unplanned shutdown if the System is running on UPS power with only 15 minutes of battery life. During an urgent unplanned shutdown, there is no requirement to gracefully shutdown software.

3.2.21.1 System Startup and Shutdown Processing

3.2.21.1.1 The System shall complete a planned shutdown within 30 minutes of its initiation. (S-2290; Common)
Requirements Trace: SRD-357

3.2.21.1.2 The System shall complete an urgent shutdown within 15 minutes of its initiation. (S-2294; Common)
Requirements Trace: SRD-358

3.2.21.1.3 The System shall be operational within one hour of a hardware restart. (S-2567; Common)
Requirements Trace: SRD-415

3.2.21.1.4 The System shall be operational within 30 minutes of a software restart. (S-2568; Common)
Requirements Trace: SRD-416

3.2.21.2 System Startup and Shutdown User Interfaces

3.2.21.2.1 The System shall provide the System Controller the capability to perform a planned shutdown of the System. (S-2288; Common)
Requirements Trace: SRD-357

3.2.21.2.2 The System shall provide the System Controller the capability to perform a startup of the System. (S-2289; Common)
Requirements Trace: SRD-415, SRD-416

3.2.21.2.3 The System shall provide the System User the capability to shutdown individual analyst workstations without affecting the operation of other analyst workstations. (S-2291; Common)
Requirements Trace: SRD-357, SRD-358

3.2.21.2.4 The System shall provide the System User the capability to startup individual analyst workstations without affecting the operation of other analyst workstations. (S-2292; Common)
Requirements Trace: SRD-415, SRD-416

3.2.21.2.5 The System shall provide the System Controller the capability to perform an urgent shutdown of the System. (S-2293; Common)
Requirements Trace: SRD-358

3.2.21.2.6 The System shall provide the System Controller the capability to start processes. (S-2295; Common)
Requirements Trace: SRD-13, SRD-288

3.2.21.2.7 The System shall provide the System Controller the capability to stop processes. (S-2296; Common)
Requirements Trace: SRD-13, SRD-288

3.2.21.2.8 The System shall provide the System Controller the capability to initiate and terminate system processing. (S-2297; Common)
Requirements Trace: SRD-317

3.2.22 Design Constraints

3.2.22.1 The System shall make use of commercial off-the-shelf (COTS) and open source software where possible. (S-2218; Common)
Requirements Trace: SRD-273

3.2.22.2 The System shall allow easy updates to commercial off-the-shelf (COTS) and open source software. (S-2219; Common)
Requirements Trace: SRD-273

3.2.22.3 The System shall reuse suitable existing software where practical. (S-5738; IDC only)
Requirements Trace: SRD-273

3.2.22.4 The System shall use relational database management systems that support ACID transactions, referential integrity and fine grained locking. (S-5831; IDC only)
Requirements Trace: SRD-461

3.2.22.5 The System shall use a distributable open source database for standalone subsystems. (S-5832; IDC only)
Requirements Trace: SRD-461

3.2.22.6 The System shall use open-source software whenever possible. (S-5739; IDC only)
Requirements Trace: SRD-460

3.2.22.7 The System shall use open-source software when both open-source and commercial software are available. (S-5740; IDC only)
Requirements Trace: SRD-460

3.2.22.8 The System software shall be written using a minimum number of programming languages. (S-2220; Common)
Requirements Trace: SRD-272

3.2.22.9 The System shall implement dates and times that include leap years and seconds. (S-2224; Common)
Requirements Trace: SRD-281

3.2.22.10 The System shall use date formats with four digit years. (S-5725; Common)
Requirements Trace: SRD-282

3.2.22.11 The System shall use year 2038 epoch rollover compliant date formats. (S-2226; Common)
Requirements Trace: SRD-282

3.2.22.12 The System software shall be maintained and controlled via configuration management software. (S-2233; Common)
Requirements Trace: SRD-298

3.2.23 Systems

The System is comprised of several subsystems each configured to meet its assigned mission. The System's primary mission is to monitor compliance of existing and future nuclear weapons testing treaties. This mission is performed by one of two subsystems - one possessing the 'primary' mission called the Operational (OPS) Subsystem and the other serving as a comparable OPS Subsystem in functionality but operates in standby mode as an Alternate (ALT) Subsystem while the 'primary' mission is performed by the OPS. Only one of these two subsystems, however, holds the 'primary' mission at any given time.

3.2.23.1 Subsystem Definition

3.2.23.1.2 The System shall be comprised of discrete subsystems each configured to support its mission, including: 1) Operational (OPS) Subsystem; 2) Alternate (ALT) Operational Subsystem; 3) Testbed (SUS/TST) Subsystem; 4) Development (DEV) Subsystem; 5) Continuous Automated Testing (CATS) Subsystem; 6) Training Subsystem; and 7) Standalone Subsystems. (S-5690; IDC only)
Requirements Trace: SRD-500

3.2.23.2 OPS/ALT Subsystems

3.2.23.2.1 The System shall provide access to all Analyst capabilities from a remote location over a secure connection. (S-5689; IDC only)
Requirements Trace: SRD-450

3.2.23.2.2 The System shall provide the System User the capability to remotely access required user interface functions on the OPS Subsystem from a remote connection over a secure connection. (S-5688; IDC only)
Requirements Trace: SRD-450

3.2.23.2.3 The System shall provide the System User the capability to remotely access required user interface functions on the Primary from the Backup. (S-2248; Common)
Requirements Trace: SRD-360

3.2.23.2.4 The System shall provide the System User the capability to remotely access required user interface functions on the Backup from the Primary. (S-2249; Common)
Requirements Trace: SRD-360

3.2.23.2.5 The System shall provide the System Controller the capability to remotely operate the Primary from the Backup. (S-2250; Common)
Requirements Trace: SRD-360

3.2.23.2.6 The System shall provide the System Controller the capability to remotely operate the Backup from the Primary. (S-2251; Common)
Requirements Trace: SRD-360

3.2.23.2.7 The System shall provide station data to external users in no more than one (1) hour following an unplanned switch between the Primary and Backup. (S-5886; IDC only)
Requirements Trace: SRD-473

3.2.23.2.8 The System shall provide the System Controller the capability to initiate a switch between the Primary and Backup. (S-5887; Common)
Requirements Trace: SRD-474

3.2.23.2.9 The System shall initiate the automatic processing of waveform data in no more than six (6) hours from the start of an unplanned switch between the Primary and Backup. (S-5888; IDC only)
Requirements Trace: SRD-475

3.2.23.2.10 The System shall provide the Analyst the capability to perform interactive reviews of processing results in no more than six (6) hours from the start of an unplanned switch between the Primary and Backup. (S-5889; IDC only)
Requirements Trace: SRD-475

3.2.23.2.12 The System shall provide the System Controller the capability to disseminate data and products in no more than six (6) hours from the start of an unplanned switch between the Primary and Backup. (S-5890; IDC only)
Requirements Trace: SRD-475

3.2.23.2.13 The ALT Subsystem shall be a copy of the OPS Subsystem in software and hardware not physically collocated with OPS. (S-5731; IDC only)
Requirements Trace: SRD-361

3.2.23.2.14 The System shall complete a planned switch between the Primary and Backup with no loss of data or data consistency. (S-5885; Common)
Requirements Trace: SRD-472

3.2.23.11 SUS/SALT/DEV Subsystem

3.2.23.11.1 The System shall forward selected waveform data and processing results data to the SUS/TST Subsystem. (S-2260; Common)
Requirements Trace: SRD-366, SRD-367, SRD-432

3.2.23.11.2 The System shall provide the System Maintainer the capability to configure the waveform and processing results data to send to the SUS/TST Subsystem. (S-2261; Common)
Requirements Trace: SRD-366, SRD-432

3.2.23.11.3 The SUS/TST Subsystem shall be a functionally redundant copy of the OPS Subsystem. (S-2262; Common)
Requirements Trace: SRD-367

3.2.23.11.4 The Development Subsystem shall provide the Developer the capability to access, modify, create, compile, run, and test source code and configuration files. (S-2264; Common)
Requirements Trace: SRD-298

3.2.23.11.5 The SUS/TST Subsystem shall provide the Developer the capability to access, modify, create, compile, run, and test source code and configuration files. (S-2265; Common)
Requirements Trace: SRD-298

3.2.23.11.6 The Development Subsystem shall provide the Developer the capability to access, modify, run, and test existing and new processes in an operational-like mode. (S-2266; Common)
Requirements Trace: SRD-299

3.2.23.11.7 The SUS/TST Subsystem shall provide the Developer the capability to access, modify, run, and test existing and new processes in an operational-like mode without affecting the OPS Subsystem. (S-2267; Common)
Requirements Trace: SRD-299, SRD-366

3.2.23.12 CATS Subsystem

3.2.23.12.1 The CATS subsystem shall provide the Developer the capability to access, modify, create, compile, run, and test software (source code and configuration files). (S-5807; IDC only)
Requirements Trace: SRD-615

3.2.23.12.2 The CATS subsystem shall test software without affecting the OPS Subsystem. (S-5808; IDC only)
Requirements Trace: SRD-615

3.2.23.12.3 The CATS subsystem shall test software on a regular basis at user defined time intervals. (S-5809; IDC only)
Requirements Trace: SRD-615

3.2.23.12.4 The CATS subsystem shall provide the Developer the capability to request the CATS subsystem to test software at user defined time intervals. (S-5810; IDC only)
Requirements Trace: SRD-615

3.2.23.12.5 The CATS subsystem shall provide the Developer the capability to perform semi-automatic testing of stations prior to release for operational use. (S-5814; IDC only)
Requirements Trace: SRD-496

3.2.23.13 Standalone Subsystem

3.2.23.13.1 The Standalone Subsystem shall be scalable to operate on a field laptop. (S-2269; Common)
Requirements Trace: SRD-216

3.2.23.13.2 The Standalone Subsystem shall be scalable to operate on a reduced data center hardware installation. (S-2270; Common)
Requirements Trace: SRD-216

3.2.23.13.3 The Standalone Subsystem shall operate on low-cost computing infrastructure including the database management system. (S-2271; Common)
Requirements Trace: SRD-216

3.2.23.13.4 The System shall provide components that can be distributed and run on the Standalone Subsystems. (S-2272; Common)
Requirements Trace: SRD-216

3.2.23.14 Training Subsystem

The Training Subsystem is a fully standalone subsystem with no external network connection. The Training Subsystem is totally geared towards new analysts.

This subsystem does not acquire data, although it does have a basic pipeline and a workflow acquisition simulator. Instead, this subsystem uses a fixed set of interesting data. This data is primarily raw data and is exported from the OPS Subsystem to physical media which is physically taken to the training site and imported; this happens infrequently (on the order of yearly).

There is a training network set up, and the instructor can see the student workstations with their work in progress and even remotely command a student's work station. Ten instructor/student workstations are a part of the Training Subsystem.

The students work in separate areas. This allows them to process the same input data but store multiple output solutions. No permanent history is retained.

The Training Subsystem is run and managed by an entirely different group than the group that manages OPS/ALT.

Periodic software upgrades happen once or twice per year.

3.2.23.14.1 The Training Subsystem shall provide the Analyst with an environment that is functionally equivalent to the OPS/ALT Subsystems. (S-2274; Common)
Requirements Trace: SRD-369

3.2.23.14.2 The Training Subsystem software shall be upgraded periodically with OPS Subsystem changes. (S-2275; Common)
Requirements Trace: SRD-370

3.2.23.14.3 The Training Subsystem shall provide 10 student workstations. (S-2276; Common)
Requirements Trace: SRD-371

3.2.23.14.4 The Training Subsystem shall include a central instructor workstation that allows interaction (including remote operation and viewing) with individual student workstations. (S-2277; Common)
Requirements Trace: SRD-371, SRD-372, SRD-376, SRD-377

3.2.23.14.5 The Training Subsystem shall include a central instructor workstation that allows simultaneous interaction (including remote operation and viewing) with all student workstations. (S-2278; Common)
Requirements Trace: SRD-371, SRD-376, SRD-377

3.2.23.14.6 The Training Subsystem shall provide the Analyst Instructor the capability to delete processing results and waveforms selected based on time interval, instructor, student, and/or dataset. (S-2279; Common)
Requirements Trace: SRD-194, SRD-378

3.2.23.14.7 The System shall provide the System User the capability to create training data sets that include selected configuration, waveforms, and processing results from selected processing stages. (S-2280; Common)
Requirements Trace: SRD-192

3.2.23.14.8 The Training Subsystem shall provide the Analyst Instructor the capability to view a report highlighting the differences between the processing results of the instructor and the processing results of a selected student. (S-2281; Common)
Requirements Trace: SRD-193

3.2.23.14.9 The Training Subsystem shall provide the Analyst the capability to view a report highlighting the differences between their processing results and the processing results of the instructor. (S-2282; Common)
Requirements Trace: SRD-133, SRD-193

3.2.23.14.10 The Training Subsystem shall provide the Analyst Instructor the capability to install waveform and processing results data using start time, end time, phenomenology and stations to select which data is to be loaded. (S-2283; Common)
Requirements Trace: SRD-133, SRD-373

3.2.23.14.11 The Training Subsystem shall provide the Analyst Instructor the capability to delete waveform and processing results data using start time, end time, phenomenology and stations to select which data is to be deleted. (S-2284; Common)
Requirements Trace: SRD-373

3.2.23.14.12 The Training Subsystem shall store data processing results and associated data for each Analyst in an independent solution set that is separate from that of other Analysts using the Subsystem. (S-2285; Common)
Requirements Trace: SRD-374, SRD-375, SRD-378

3.2.23.14.13 The Training Subsystem shall have individual accounts for each student. (S-2286; Common)
Requirements Trace: SRD-374

3.2.24 Hardware

3.2.24.1 Reliability, Maintainability, Availability

3.2.24.1.1 The System shall automatically backup all data. (S-2314; Common)
Requirements Trace: SRD-334

3.2.24.1.2 The System shall maintain a mission profile operating 52 weeks a year, 7 days per week, and 24 hours a day. (S-2317; Common)
Requirements Trace: SRD-336

3.2.24.1.3 The Training Subsystem shall support mission duration of eight hours per day, five days per week, 250 days per year. (S-2322; Common)
Requirements Trace: SRD-345

3.2.24.2 Data Storage
The System provides data storage for processing incoming seismic, hydroacoustic, and infrasound data originating from stations located around the world.

This processing includes: 1) processing of incoming raw data; 2) all routine automatic processing; and 3) all interactive analysis of data.

Although the majority of incoming raw data are processed on a continuous basis, some data are processed as per request.

3.2.24.2.1 The System shall store on the System all existing data and five (5) additional years of data. (S-2331; Common)
Requirements Trace: SRD-349

3.2.24.2.2 The Training Subsystem shall provide storage with sufficient capacity to accommodate thirty (30) days of multi-phenomenology waveform data for stations available on the OPS Subsystem. (S-2332; Common)
Requirements Trace: SRD-351

4 SPECIFICATION TRACEABILITY

System Requirements (SRD)	System Specifications (SSD)
SRD-9	S-1199, S-1204, S-1205, S-1207, S-1208, S-3130
SRD-10	S-1203, S-1210
SRD-11	S-1150, S-1151, S-1152, S-1153
SRD-12	S-1154, S-1155
SRD-13	S-1180, S-1181, S-2295, S-2296
SRD-15	S-1241, S-5584, S-5585
SRD-21	S-5613, S-5614
SRD-22	S-1220, S-1227, S-1228, S-5781, S-5782, S-5783, S-5784
SRD-25	S-1229, S-5581, S-5582, S-5583
SRD-29	S-1253, S-1254, S-1255, S-1256, S-1257, S-1258, S-1259, S-1260, S-1261, S-1262, S-1264, S-1265, S-1266, S-1267, S-1268, S-1269, S-1270, S-1271, S-1275, S-1276, S-1278, S-1280, S-5592, S-5593, S-5594, S-5595
SRD-30	S-1285, S-1286, S-1287, S-1288, S-1289, S-1290, S-1291, S-1298, S-1299, S-1300, S-1301, S-1306, S-1307, S-1308
SRD-31	S-1272, S-1281, S-1282, S-1294
SRD-32	S-1302, S-1303, S-1304, S-1305
SRD-33	S-1273, S-1284, S-1296, S-1297
SRD-34	S-1284, S-1285
SRD-38	S-1312, S-1313, S-1314, S-1315, S-1316, S-1317, S-1318, S-1319, S-1323, S-1324, S-1327, S-1331, S-1332, S-1333, S-1334, S-1335, S-1336, S-1337, S-1338, S-1339, S-1340, S-1341, S-1342, S-1343, S-1344, S-1346, S-1347, S-2418
SRD-39	S-1320, S-1321, S-1322, S-1323
SRD-41	S-1453, S-1454, S-1455, S-1457, S-1458, S-1460, S-1461, S-1462, S-1465
SRD-42	S-1468, S-1469, S-1470, S-1473, S-1474, S-1475, S-1478, S-1479, S-1481, S-1482, S-1483, S-1486, S-2359
SRD-44	S-1441, S-1443, S-1445, S-1446, S-1447, S-1450
SRD-52	S-1411, S-1412, S-1413
SRD-54	S-1271, S-1409, S-1410, S-5593, S-5594
SRD-55	S-1406
SRD-56	S-1408, S-1429, S-1443, S-1457, S-1473
SRD-62	S-1318, S-1326, S-1335, S-1336, S-1337, S-1425, S-1429, S-1430, S-1432, S-1433, S-1438, S-1441, S-1443, S-1445, S-1446, S-1450, S-5630, S-5631, S-5632
SRD-63	S-1862, S-1863, S-1870

SRD-64	S-1490, S-1491, S-1493, S-1494, S-1495, S-1496, S-1497, S-1498, S-1525, S-1561, S-2414, S-2415, S-2416, S-5635, S-5636, S-5637, S-5638, S-5644, S-5647
SRD-65	S-1508, S-1509
SRD-66	S-1426
SRD-67	S-1471, S-1473, S-1474, S-1476, S-1480
SRD-71	S-1518, S-1806, S-1807, S-1811
SRD-72	S-1514, S-5596, S-5597, S-5598, S-5599
SRD-73	S-1504, S-1540
SRD-74	S-1490, S-1493, S-1495, S-1496, S-1507, S-1508, S-1509, S-1510, S-1511, S-1520, S-1521, S-1523, S-1524, S-1525, S-1561, S-5600, S-5601
SRD-75	S-1489, S-1490, S-1491, S-2411, S-2412, S-2413, S-2414, S-2415, S-2416, S-5626, S-5633, S-5634, S-5635, S-5636, S-5637, S-5638
SRD-76	S-1494, S-1497, S-1498, S-1504, S-1511, S-1520, S-1521, S-1522, S-1523, S-1524, S-1540, S-1560, S-2414, S-2415, S-2416, S-5627, S-5628, S-5629, S-5639, S-5640
SRD-77	S-1504, S-1511, S-1512, S-1513, S-1520, S-1521, S-1522, S-1524, S-1526, S-1540, S-1560, S-3026
SRD-78	S-1490, S-1504, S-1507, S-1508, S-1509, S-1510, S-1561
SRD-79	S-1504, S-1505, S-1506, S-1540, S-1541, S-1542, S-1549, S-1556, S-1560, S-1863, S-2342
SRD-80	S-1520, S-1521, S-1522, S-1955, S-1961, S-1962, S-1963, S-1964
SRD-81	S-1540, S-1541, S-1542, S-1548, S-1549, S-1862, S-1863, S-1870, S-2342
SRD-82	S-1547, S-1548, S-1551, S-1556
SRD-83	S-1543, S-1544, S-1548, S-1863
SRD-84	S-1515
SRD-85	S-1572, S-1579, S-1580, S-1586, S-1588
SRD-86	S-1581, S-1582, S-1584, S-5620
SRD-87	S-1580
SRD-88	S-1579, S-1580, S-1586, S-1588
SRD-89	S-1504, S-1567, S-1568, S-1569, S-1572, S-1574, S-1576
SRD-92	S-1563, S-1564, S-1592, S-1595, S-1596, S-1600, S-1603, S-1604, S-1607, S-1608, S-1619, S-1620, S-1640
SRD-93	S-1631
SRD-94	S-1618, S-1623, S-1633, S-1634, S-1636, S-1637
SRD-95	S-1616, S-1625
SRD-96	S-1532, S-1626, S-1627, S-1628
SRD-97	S-1564, S-1595, S-1596, S-1607, S-1608, S-1619, S-1620
SRD-98	S-1976, S-1977, S-1978, S-1979, S-1991, S-1992, S-1993, S-2597
SRD-99	S-1505, S-1506

SRD-100	S-1597, S-1598, S-1599, S-1609
SRD-101	S-1593, S-1594
SRD-102	S-1427, S-1592, S-1601, S-1606, S-1621, S-1622
SRD-103	S-1416, S-1435, S-1603, S-1604, S-1610, S-1611, S-1612, S-1613, S-1614, S-1661
SRD-106	S-1650, S-1651, S-1653, S-1655, S-1656, S-1657, S-1659, S-1664, S-1665
SRD-107	S-1650
SRD-108	S-1652, S-1663
SRD-110	S-1660, S-1661, S-2036, S-2038
SRD-120	S-2127, S-2128, S-2144, S-2156
SRD-122	S-1949, S-1954, S-1958, S-1960, S-1968, S-1969
SRD-124	S-1189, S-1284, S-1285, S-1286, S-1287, S-1288, S-1289, S-1290, S-1291, S-1292, S-1293, S-1306, S-1308, S-1331, S-1332, S-1333, S-1334, S-1335, S-1336, S-1337, S-1338, S-1339, S-1340, S-1341, S-1342, S-1343, S-1344, S-1352, S-1353, S-1370, S-1371, S-1372, S-1373, S-1374, S-1375, S-1376, S-1377, S-1378, S-1379, S-1380, S-1381, S-1382, S-1383, S-1416, S-1417, S-1418, S-1419, S-1432, S-1433, S-1434, S-1435, S-1436, S-1445, S-1446, S-1447, S-1460, S-1461, S-1462, S-1478, S-1479, S-1480, S-1481, S-1482, S-1516, S-1517, S-1529, S-1530, S-1531, S-1532, S-1533, S-1534, S-1535, S-1536, S-1537, S-1554, S-1586, S-1606, S-1607, S-1608, S-1609, S-1610, S-1611, S-1612, S-1613, S-1614, S-1615, S-1616, S-1636, S-1637, S-1642, S-1643, S-1644, S-1645, S-1646, S-1659, S-1660, S-1661, S-1706, S-1707, S-1708, S-1709, S-1728, S-1729, S-1730, S-1731, S-1732, S-1733, S-1811, S-1812, S-1814, S-1872, S-1878, S-1879, S-1885, S-1887, S-1888, S-1889, S-1890, S-1891, S-1892, S-1893, S-1894, S-1895, S-1896, S-1897, S-1898, S-1899, S-1900, S-1901, S-1902, S-1903, S-1904, S-1905, S-1906, S-1907, S-1908, S-1915, S-1916, S-1917, S-1918, S-1919, S-1920, S-1921, S-1922, S-1923, S-1924, S-1926, S-1927, S-1928, S-1929, S-1930, S-1938, S-1939, S-1940, S-1941, S-1942, S-1943, S-1946, S-1947, S-1985, S-1986, S-1987, S-1988, S-1989, S-1990, S-1991, S-1992, S-1993, S-1995, S-1996, S-1997, S-1998, S-2019, S-2040, S-2099, S-2100, S-2101, S-2102, S-2103, S-2104, S-2110, S-2129, S-2130, S-2167, S-2168, S-2170, S-2176, S-2420, S-2595, S-2597, S-2607, S-3023, S-3024, S-3025, S-5603, S-5604, S-5851, S-5852, S-5853
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SRD-126	S-1946, S-1957
SRD-127	S-1887, S-1888
SRD-128	S-1919
SRD-129	S-1640, S-1642, S-1643, S-1644, S-1645, S-1646
SRD-130	S-1157, S-2123

SRD-131	S-1157, S-1158, S-1159
SRD-133	S-1889, S-1920, S-1923, S-1924, S-2282, S-2283, S-5556
SRD-135	S-1436, S-1463, S-1484, S-5621
SRD-136	S-1189, S-1284, S-1285, S-1286, S-1287, S-1288, S-1289, S-1290, S-1291, S-1292, S-1293, S-1306, S-1307, S-1308, S-1331, S-1332, S-1333, S-1334, S-1335, S-1336, S-1337, S-1338, S-1339, S-1340, S-1341, S-1342, S-1343, S-1344, S-1352, S-1353, S-1370, S-1371, S-1372, S-1373, S-1374, S-1375, S-1376, S-1377, S-1378, S-1379, S-1380, S-1381, S-1382, S-1383, S-1416, S-1417, S-1418, S-1419, S-1432, S-1433, S-1434, S-1435, S-1436, S-1445, S-1446, S-1447, S-1460, S-1461, S-1462, S-1478, S-1479, S-1480, S-1481, S-1482, S-1516, S-1517, S-1529, S-1530, S-1531, S-1532, S-1533, S-1534, S-1535, S-1536, S-1537, S-1554, S-1586, S-1606, S-1607, S-1608, S-1609, S-1610, S-1611, S-1612, S-1613, S-1614, S-1615, S-1616, S-1636, S-1637, S-1642, S-1643, S-1644, S-1645, S-1646, S-1659, S-1660, S-1661, S-1706, S-1707, S-1708, S-1709, S-1728, S-1729, S-1730, S-1731, S-1732, S-1733, S-1811, S-1812, S-1814, S-1872, S-1878, S-1879, S-1887, S-1888, S-1889, S-1892, S-1893, S-1894, S-1895, S-1896, S-1897, S-1898, S-1899, S-1900, S-1901, S-1902, S-1903, S-1904, S-1905, S-1906, S-1907, S-1908, S-1915, S-1916, S-1917, S-1918, S-1919, S-1920, S-1921, S-1922, S-1923, S-1924, S-1926, S-1927, S-1928, S-1929, S-1930, S-1938, S-1939, S-1940, S-1941, S-1942, S-1943, S-1946, S-1947, S-1967, S-1985, S-1986, S-1987, S-1988, S-1989, S-1990, S-1991, S-1992, S-1993, S-1995, S-1996, S-1997, S-1998, S-2019, S-2040, S-2099, S-2100, S-2101, S-2102, S-2103, S-2104, S-2110, S-2129, S-2130, S-2168, S-2170, S-2176, S-2420, S-2597, S-2607, S-3023, S-3024, S-3025, S-5603, S-5604, S-5851, S-5852, S-5853
SRD-137	S-1809, S-1811
SRD-138	S-1516, S-1517, S-1527, S-1533, S-1534, S-1535, S-1536, S-1554, S-1556, S-1927, S-1928, S-1929, S-1930, S-2607, S-3024
SRD-139	S-1916, S-1920, S-1926, S-1930
SRD-140	S-1872, S-1920
SRD-141	S-1916, S-1917, S-1918
SRD-142	S-1533, S-1534, S-1535, S-1927, S-1928, S-1929, S-3023, S-3025
SRD-144	S-1361, S-1373, S-1976, S-1981, S-1983
SRD-145	S-1377, S-1378, S-1379, S-1382
SRD-149	S-1985, S-1986, S-1987
SRD-150	S-1985, S-1986, S-1987
SRD-151	S-1981, S-1983, S-1989, S-1990, S-5603, S-5604
SRD-152	S-1976, S-1977, S-1978, S-1979, S-1991, S-1992, S-1993, S-2597
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SRD-156	S-1975, S-1976, S-1977, S-1978, S-1979, S-1995, S-1996, S-1998, S-1999, S-2000
SRD-160	S-2003, S-2006, S-2015, S-2016, S-5695, S-5696, S-5697, S-5758
SRD-163	S-1226, S-2003, S-2006, S-2007, S-2012, S-2019, S-2024
SRD-165	S-1226, S-2017, S-2020, S-2021, S-2022
SRD-168	S-2048, S-2049, S-2056, S-2057
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SRD-174	S-1177, S-1195, S-2024
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SRD-184	S-2068, S-2069
SRD-185	S-2167, S-2169, S-5708, S-5709
SRD-186	S-2168, S-2170, S-5712, S-5713
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SRD-189	S-1146, S-1147, S-1195, S-1296, S-1297, S-1298, S-1299, S-1300, S-1301, S-1302, S-1303, S-1304, S-1305, S-1306, S-1307, S-1308, S-1346, S-1347, S-1386, S-1387, S-1421, S-1438, S-1450, S-1465, S-1486, S-1495, S-1496, S-1498, S-1525, S-1556, S-1557, S-1576, S-1588, S-1619, S-1620, S-1621, S-1622, S-1623, S-1624, S-1625, S-1626, S-1627, S-1628, S-1663, S-1664, S-1665, S-1666, S-1711, S-1712, S-1713, S-1714, S-1715, S-1716, S-1717, S-1718, S-1719, S-1735, S-1736, S-1737, S-1738, S-1816, S-1817, S-1818, S-1819, S-1820, S-1821, S-1822, S-1823, S-1824, S-1842, S-1843, S-1967, S-1969, S-2042, S-2043, S-2044, S-2117, S-2118, S-2119, S-2134, S-2135, S-2156, S-2157, S-2417, S-2420, S-5714, S-5715, S-5716, S-5717, S-5720, S-5722
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SRD-193	S-2281, S-2282
SRD-194	S-2279
SRD-197	S-1779, S-1780, S-1781, S-1782, S-1811, S-1816, S-1819, S-1820
SRD-198	S-1783, S-1784, S-1785, S-1786, S-1811, S-1816, S-1819, S-1820
SRD-199	S-1787, S-1788, S-1789, S-1790, S-1811, S-1816, S-1821, S-1822, S-5829, S-5830
SRD-200	S-1791, S-1792, S-1793, S-1794, S-1811, S-1816, S-1823, S-1824
SRD-201	S-1795, S-1796, S-1797, S-1798, S-1799, S-1800, S-1811, S-1816, S-1823, S-1824
SRD-202	S-1801, S-1802, S-1803, S-1804, S-1811, S-1816, S-1823, S-1824
SRD-203	S-1776, S-1777, S-1778, S-1808, S-1812, S-1813, S-1817, S-1818
SRD-204	S-1776, S-1777, S-1808, S-1812, S-1817, S-1818

SRD-205	S-1851
SRD-206	S-1795, S-1796, S-1797, S-1801, S-1802, S-1852, S-1853, S-1855, S-1856, S-5772, S-5773, S-5774, S-5828
SRD-209	S-1811, S-1816, S-1827, S-1828, S-1829, S-1830, S-1842, S-1843, S-3041, S-3042, S-3045
SRD-211	S-1811, S-1816, S-1837, S-1838, S-1839, S-1840, S-1842, S-1843, S-3043, S-3044, S-3045
SRD-212	S-1776, S-1777, S-1808, S-1812, S-1817, S-1818
SRD-213	S-1846, S-1847, S-1848, S-1849, S-1850
SRD-216	S-2269, S-2270, S-2271, S-2272
SRD-217	S-1541, S-1867, S-1868, S-1869
SRD-218	S-1878, S-1879
SRD-220	S-5792, S-5793
SRD-225	S-2144, S-2147, S-2148, S-2151, S-2152, S-2156
SRD-226	S-2143, S-2144, S-2149, S-2150, S-2153, S-2154
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SRD-228	S-1961, S-1965, S-1970, S-1971, S-2139
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