CRYSTAL INSTRUMENTS

GROUND VIBRATION TESTING SYSTEMS

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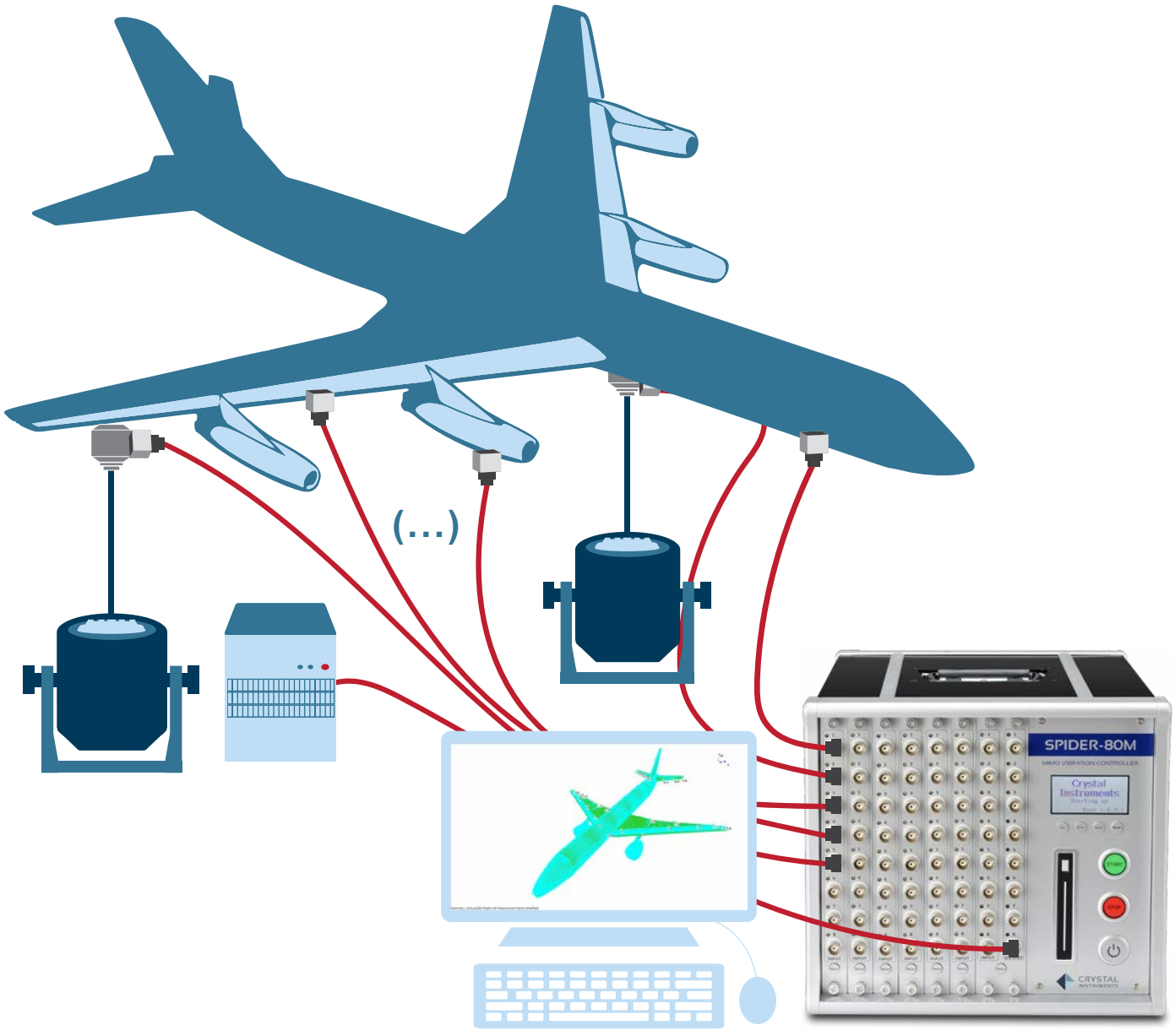

Ground Vibration Testing Solutions

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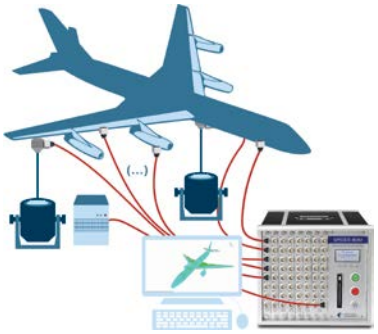


Ground Vibration Tests (GVT)

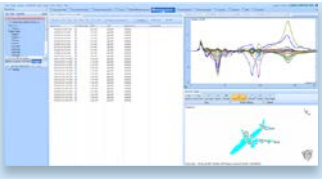
Modal Measurements using Spider-80M & EDM Modal

Modal Paramaters obtained with EDM Modal

Ground Vibration Testing (GVT) includes the modal analysis of an aircraft and its sub-assembly components to analyze and detect any changes to their structural properties. The modal parameters determined through testing are then used to validate the analytical models. The modal characteristics are also used to predict the flutter of the aircraft in order to create a safe flight envelope before flight operation.

Multiple accelerometers are mounted on the aircraft and multiple modal shakers are used to excite the aircraft to obtain multiple-reference frequency response functions (FRFs). A high-channel count data acquisition system helps users efficiently process high channel test datasets. Several output excitation types (such as Random, Sine etc.) can be used for Multiple-Input Multiple-Output (MIMO) modal tests.

A modal test of an aircraft is usually carried out in a single run to capture the response of entire assembly. A mesh grid with the measurement points is laid out and the geometry model (usually obtained from FEA or CAD model) is imported into the EDM Modal software.



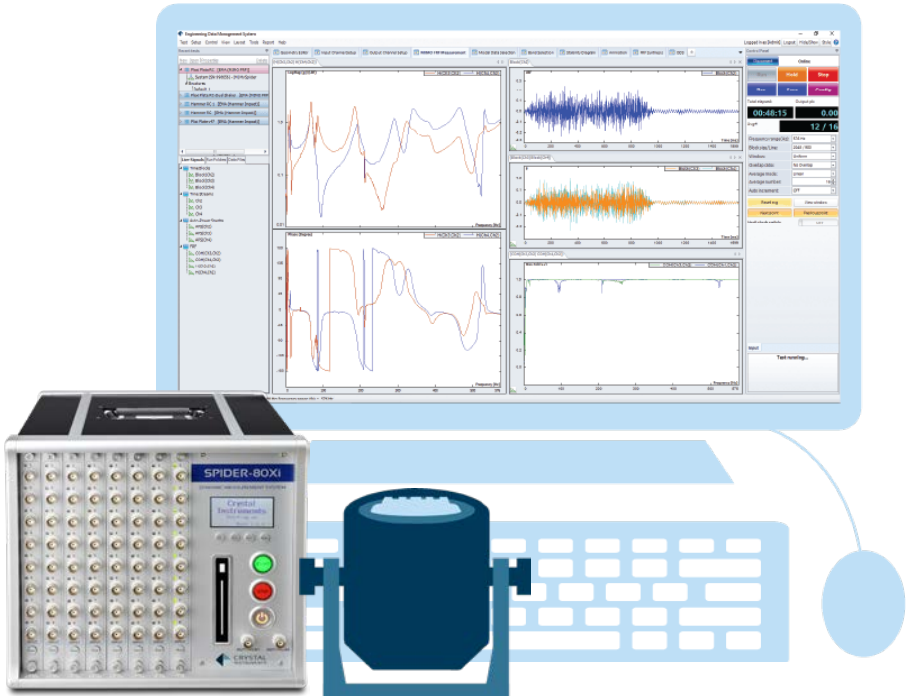
The FRFs obtained between the excitation and the response points are overlapped to observe the dominant peaks in the desired frequency range. The imaginary part of the FRFs can also be overlaid to notice the phase relationship between the measurement DOFs.

Post-processing this data to curve-fit the measured FRFs assists in acquiring the natural frequencies, damping ratios and mode shapes of the complete airplane assembly.

Good correlation between the experimental and FEA test results helps users validate the aircraft assembly and certifies it for other tests such as Normal Mode testing, etc. These tests declare that the aircraft is safe for flying.

Single-Input Multiple-Output (SIMO) FRF Testing

www.crystalinstruments.com/single-input-multiple-output-simo-frf-testing



Software Features
Ease of use testing process
Point/direction auto/manual increment
One excitation (reference)
Source trigger mode for synchronized acquisition and source excitation
Random, burst random, pseudo random, period random, chirp/burst chirp output types
Delay block and cyclic block number setting for pseudo/periodic random
Scope tab to view channel data before measurement
H1, H2, H3 and Hv estimation

EDM Modal SIMO FRF Testing includes a dedicated test setup and operation process flow using a single shaker to acquire FRF signals. Using a large channel count data acquisition system (i.e., Spider- 80X or Spider-80Xi), this shaker excitation method provides much higher test execution efficiency for the FRF measurements and minimizes the crest factor of applied forces.

The Source Output type supports pure random (white noise), burst random, Chirp/Burst Chirp, pseudo random, and periodic random. For periodical random types (pseudo random and periodical random), the delay block and cyclic block numbers can be set for the purpose of bringing the structure to steady state response prior to each data acquisition. This will result in leakage-free measurements that do not require the use of a tapering window function.

The modal analysis process is seamlessly integrated with the MIMO FRF testing.

Multiple-Input Multiple-Output (MIMO) FRF Testing

www.crystalinstruments.com/multiple-input-multiple-output-mimo-frf-testing

Software Features
Ease of use testing process
Point/direction auto/manual increment
Synchronized outputs
Multiple excitations (references)
Source trigger mode for synchronized acquisition and source excitation
Random, burst random, pseudo random, period random, chirp/burst chirp output types
Delay block and cyclic block number setting for pseudo/periodic random
Scope tab to view channel data before measurement
H1, H2, H3 and Hv estimation

EDM Modal MIMO FRF Testing includes a dedicated test setup and operation process flow using multiple simultaneous shakers to acquire FRF signals. Using a large channel count data acquisition system (i.e., Spider-80X or Spider-80Xi), this shaker excitation method provides much higher efficiency and accuracy for the FRF measurements while minimizing local stresses on the test article.

When using multiple shaker random excitation applications, the shaker-driving Source signals are guaranteed to be uncorrelated with one another. The Source Output type supports pure random (white noise), burst random, chirp/burst chirp, pseudo random, and periodic random. For periodic random types (pseudo random and periodic random), the delay block and cyclic block numbers can be set so that the structure exhibits steady-state response, allowing precise window-free analysis.

Multiple shaker excitation is useful to separate and clearly identify repeated roots and frequency-proximate modes. With more than one reference shaker, multiple columns of the Frequency Response Matrix can be measured simultaneously. Combined with the poly reference curve fitting algorithm, the modal participation factor will help to isolate the repeated and highly coupled modes.

The modal analysis process is seamlessly integrated with the MIMO FRF testing.

Multiple-Input Multiple-Output (MIMO) Sine Testing

www.crystalinstruments.com/mimo-sine-test

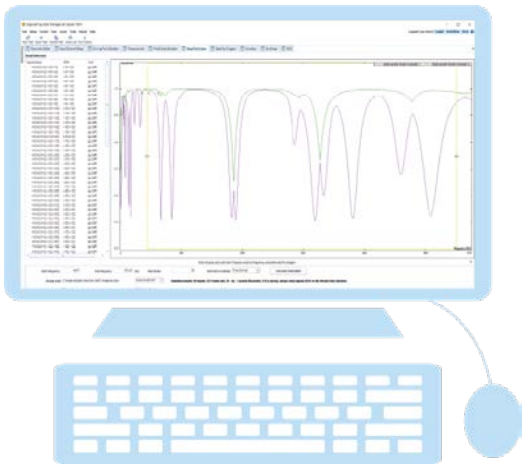
Software Features
Ease of use testing process
Point/direction auto/manual increment
Multiple swept & stepped sine excitations
Multiple number of sweeps
Testing Plan for the process and status
Specify source output level; or control the amplitude of multiple input channels
Multiple sine excitation with sine tone (references)
Specify source output level; or control the amplitude of one input channel
Linear, Logarithmic sweep mode
Filter, RMS, Mean or Peak for measurement strategy
Fixed or proportional tracking filter, with user defined bandwidth
User defined Start/end frequency; Number of points; Delta F (or Points/Oct); Sweep Speed; Transition speed

EDM Modal Sine Testing includes a dedicated test setup and operation process flow using a single or multiple modal shakers outputting a sine wave to acquire FRF signals. The Source Output type is either Swept sine or Stepped sine. The sweep mode can be linear or logarithmic. The FRF signals of each measurement DOFs with respect to defined reference DOF will be constructed. The output drive level can be defined to run the test under no control strategy, or the response of a control channel can be specified to run the test in a closed loop.

Post Processing with Modal Analysis

www.crystalinstruments.com/modal-analysis

Software Features
Modal Data Selection: Review measured FRFs, Signal Smoothing with Deconvolution (for OMA testing only)
Band Selection: Multivariate MIF, Complex MIF, Real MIF, Imag sum MIF with auto pole selection
Stability Diagram: Curve fitting method: LSCE, PTD, Poly-X, SSI with Frequency & Damping Tolerances
Least square frequency domain (LSFD) algorithm for mode shape calculation
Save/append modes to the shape table
Auto/Cross MAC calculation and display
Import/Export Modes: UFF format
Animation equation editor for unmeasured DOFs
Mode Shape Animation: wireframe, surface contour, FFD, animation with interpolation
Contour edit, Contour value
Animation smoothing, animation with un-deformed elements
Mode Shape Animation speed control (fast, slow), magnitude control (increase, decrease)
Animation Format: Single, Left/Right, Upper/Lower
Modal Shape video saving, graph saving
Synthesized FRF vs. measured FRF, with Correlation and Error values



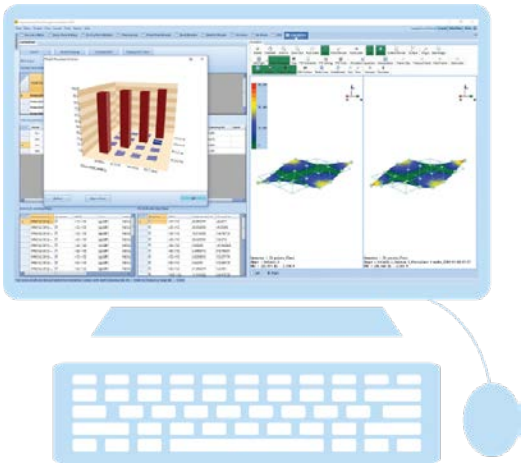
Upon completion of the Modal testing, the set of FRF data is made available for the next step of Modal Analysis which provides the user with a complete arsenal of tools, from FRF data selection and parameter identification to results validation and mode shape animation.

Mode Indicator Functions (MIFs) available in Band Selection aide in identifying repeated roots and closely-spaced distinct modes. The curve-fitters available in Stability Diagram facilitate in obtaining the modal parameters. Tools like Modal Assurance Criterion (MAC) and FRF synthesis provide means for validation of the modal parameters.

Correlation Analysis to Validate Aircraft Assembly

www.crystalinstruments.com/correlation-analysis

Software Features
Import Model: .xml, .unv, .nas
Import Mode Shape: .unv
Modal mapping: Manually pair 3 points from each model (or more), Auto-Match
Cross-MAC calculation and display
Animation Comparison: Left/Right, Upper/Lower

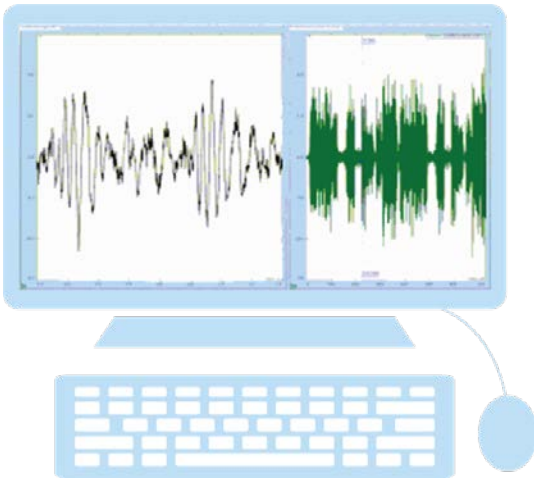


EDM Modal Correlation Analysis allows the user to correlate two modal models. The modal models can be EMA model, and/or FEA model. Comparing the experimental data with that acquired through finite element analysis helps in validating the test results. The geometry model and mode shape data from the FEA software or another set of mode shape data from EMA can be imported. A modal mapping procedure is executed to match the EMA and FEA models. After this matching procedure, the new mode shape information from FEA is interpolated and the FEA modal parameters are displayed alongside with EMA results. Finally, to observe the correlation between the results from two methods, a Cross-MAC matrix is calculated and shown.

Time Waveform Recording

www.crystalinstruments.com/time-waveform-recording

Establishing a time record of data is a critical requirement of vibration testing. Whether the application is ground vibration monitoring of railway activity or laboratory testing of a missile fixture, time recording can reveal important data. Times of peak activity, the overall vibration level at various times, the damping ratio, or other useful information is uncovered from acquired time data. Acquired vibration data might need synchronization with other data types.



Spider-80M MIMO Test Controller

www.crystalinstruments.com/spider80m-mimo-vibration-controller

Spider-80M chassis contains up to 64 channels (56 inputs and up to 8 outputs). Multiple chassis combine to form one system with up to 504 input channels and 8 output channels.

Based on Spider-80Xi Architecture

The Spider-80M platform is based on the efficient Spider-80Xi architecture and is dedicated to MIMO VCS control and MIMO structural testing applications. Each Spider-80M chassis features 8 outputs capable of carrying out 6-degree of freedom MIMO testing. One Spider-80M chassis and multiple Spider-80Xi chassis can chain together to form a very large system with up to 504 input channels.

Expand Channel Count

In a Spider-80M hardware chassis a master module with 8-inputs and 8-outputs will always be installed. This master module takes the space of two slots of Spider-80Xi module in the S80M-A35-8N chassis. Up to 6 additional Spider-80Xi front-end modules can be inserted to form a system with 8 outputs and up to 56 inputs.

The Spider-80M chassis can combine with multiple Spider-80Xi chassis to form a system with up to 504 input channels, all sampled simultaneously. Accurate time synchronization results in excellent phase match in the frequency domain between all channels, either on the same Spider front-end or across different front-ends. Channel phase match, even between separate Spider front-ends, is within 1.0 degree at 20 kHz which is suitable for high quality structural and acoustics applications requiring cross channel measurement.

Measured Unit Types

The Spider front-end systems can measure a large range of engineering units. Configure a testing system with different Spider front-ends to measure and record vibration, acceleration, velocity, displacement, LVDT, RVDT, strain gage, pressure, temperature, etc.

Mass Storage

A high-performance removable 2.5-inch solid-state drive is used as storage media. When recorded, data will be written in the NTFS file format. Data is extracted from the Spider-NAS using EDM software to transfer data to the PC. Alternatively, the solid-state drive can be physically removed and connected to extract data to the PC.

The Spider-80M ships with an internally installed a 250 GB solid-state drive. The drive can be upgraded up to 2 TB. The solid-state drive performs well in the high shock and vibration environment. A special error-checking algorithm developed by Crystal Instruments detects and avoids any errors that may occur in the data transfer and storage.

Time Synchronization

Through the Ethernet connection, multiple Spider-80Xi or Spider-80M chassis can be synchronized through the IEEE 1588v2 protocol. The synchronization accuracy is within nanoseconds when a specified network switch is used. The data acquired by all the measurement channels will be on the same time base. Phase match between channels across different Spider front-ends is within nanoseconds.

The Front-ends of the Spider-80Xi and Spider-80M Platform					
Front-end Types	**Spider-80Hi**	**Spider-80Ci**	**Spider-80Gi**	**Spider-80SGi**	**Spider-80Ti**
Max Sampling Rate	256 kHz	256 kHz	25.6 kHz	256 kHz	1 kHz
Number of Inputs Per Front-end	8	8	16	8	16
Connector Type	BNC	BNC	50 pin D-Sub	LEMO	6-pin pluggable terminal blocks
Input Type	IEPE Voltage TEDS	IEPE Voltage TEDS Charge	Strain gage-based sensors	Voltage Strain gage Strain gage-based sensors MEMS DC-based sensors IEPE	3-wire RTD K type thermocouple
Input Coupling	AC Differential DC Differential AC Single-ended DC Single-ended	AC Single-ended DC Single-ended	AC Differential DC Differential	AC Differential DC Differential Bridge-Based Sensor In-line Charge Amplifier	PT 100 (RTD) K-Type input (TC)
Sensor Excitation	4.2 mA at 21 V for IEPE	4.2 mA at 21 V for IEPE	+/-2.5 V, +/-5 V	+/2.5 V, +/5 V, 10 V 22 V for IEPE	10 µA to 1.5 mA RTD
Strain Gage Type	-------	-------	Quarter Bridges (Type I,II, 3 – Wire Quarter Bridge) Half Bridge (Type I,II) Full Bridge (Type I,II) Excitation voltage: ±2.5, ±5	Quarter Bridge (Type I, II) Half Bridge (Type I, II) Full Bridge Type (I, II) Excitation voltage: ±2.5, ±5	
Max Input Range	±20 V_{pk}	±20 V_{pk}	±10 mV, ±100 mV, ±1 V, ±10 V	±10 mV, ±100 mV, ±1 V, ±10 V	400 Ohm (RTD) ±80 mV (TC)
Input Protection Voltage	±220 V	±220 V	±40 V	±40 V	-------
Analog to Digital Converter Per Channel	Dual 24-bit ADC	Dual 24-bit ADC	24-bit ADC	24-bit ADC	24-bit ADC
Cross Talk	< -100 dB	< -100 dB	< -130 dB	< -100 dB	-------
Amplitude Accuracy	±0.1% at 1 kHz 1 V	±0.1% at 1 kHz 1 V	0.1% typical, Less than 1.5% (up to 10 KHz), cable length up to 1000 ft (18AWG)	±0.1%	-------
Phase Match	< 1° up to 20 kHz	< 1° up to 20 kHz	< 1° up to 20 kHz	< 1° up to 20 kHz	-------

Comprehensive Technology Service Agreement

www.crystalinstruments.com/technology-service-agreement

Crystal Instruments understands the enormous investment our clients put into our products. We match their investment by offering the most comprehensive technical support agreement in the industry. From support calls to staff training, Crystal Instruments provides solutions to our customers' needs.

The "Comprehensive Technology Support Agreement" offered by Crystal Instruments is fairly priced as a small percentage of the total purchase value. The services offered and included in the agreement are for the duration of 1 year. The agreement is renewable at a locked in rate as a subscription. Rates are subject to increase if a subscription is not continued at the time of renewal and signed up for at a later time. Please contact Crystal Instruments for pricing information.

Services offered are:

- Annual software upgrade program - accessible by convenient online downloads
- Annual hardware calibration
- Priority phone/email/live video support from highly trained engineers
- Temporary replacement unit for hardware in 48 hours
- Data recovering services
- Hardware repair when the total service hours required is less than 4 hours per incident

Annual Hardware Calibration

Crystal Instruments DMS is certified by ISO:9001. Hardware calibrations are also performed at the customer's site upon request. Customers with a Premier Technology Service Agreement will receive standard annual hardware calibration services at no additional cost (a $1500 value).

Annual Software Upgrades

Crystal Instruments provides convenient solutions for software upgrades. Users are able to download the latest versions of Crystal Instruments' Engineering Data Management (EDM) software through the support website.

Other options include emailed links to download software updates, physical CD-ROMs sent to your location, and installation instructions provided over the phone by our highly qualified Applications Engineers. Customers with a Premier Technology Service Agreement will receive standard software update services at no additional cost.

Temporary Replacement Units

Crystal Instruments strives to minimize any inconvenience to our customers' operations. Temporary replacement units are often provided to customers as a solution. Units will usually be assigned to customers within 48 hours or less.

Live Product Support

Crystal Instruments support staff is based in Santa Clara, CA at our corporate headquarters. Our support staff provides phone and email support from 8am to 5pm PST, Monday through Friday. All support is provided by highly trained engineers, not technicians. After hours support is also available upon request.

Crystal Instruments' highly diverse staff provides native language support in English, Spanish, Mandarin, Cantonese, Japanese, Taiwanese, Persian, Hindi, and Vietnamese.

Hardware Repair Services

Crystal Instruments provides hardware repair for units estimated to have a 4 hour or less repair service period. Additional hours required for repairs are charged at an hourly rate. Replacement parts are discounted by 30% under the Premier Technology Support Agreement. All hardware repair takes place at Crystal Instruments headquarters in Santa Clara, CA. Our highly trained technicians will accurately and efficiently repair your equipment in our ISO:9001 certified facilities.

Data Recovery Services

Crystal Instruments understands the importance of recovering any lost data safely and securely. Our staff is ready and available to assist you through any data loss crisis.

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