CRYSTAL INSTRUMENTS

# EDM MODAL: TESTING & ANALYSIS

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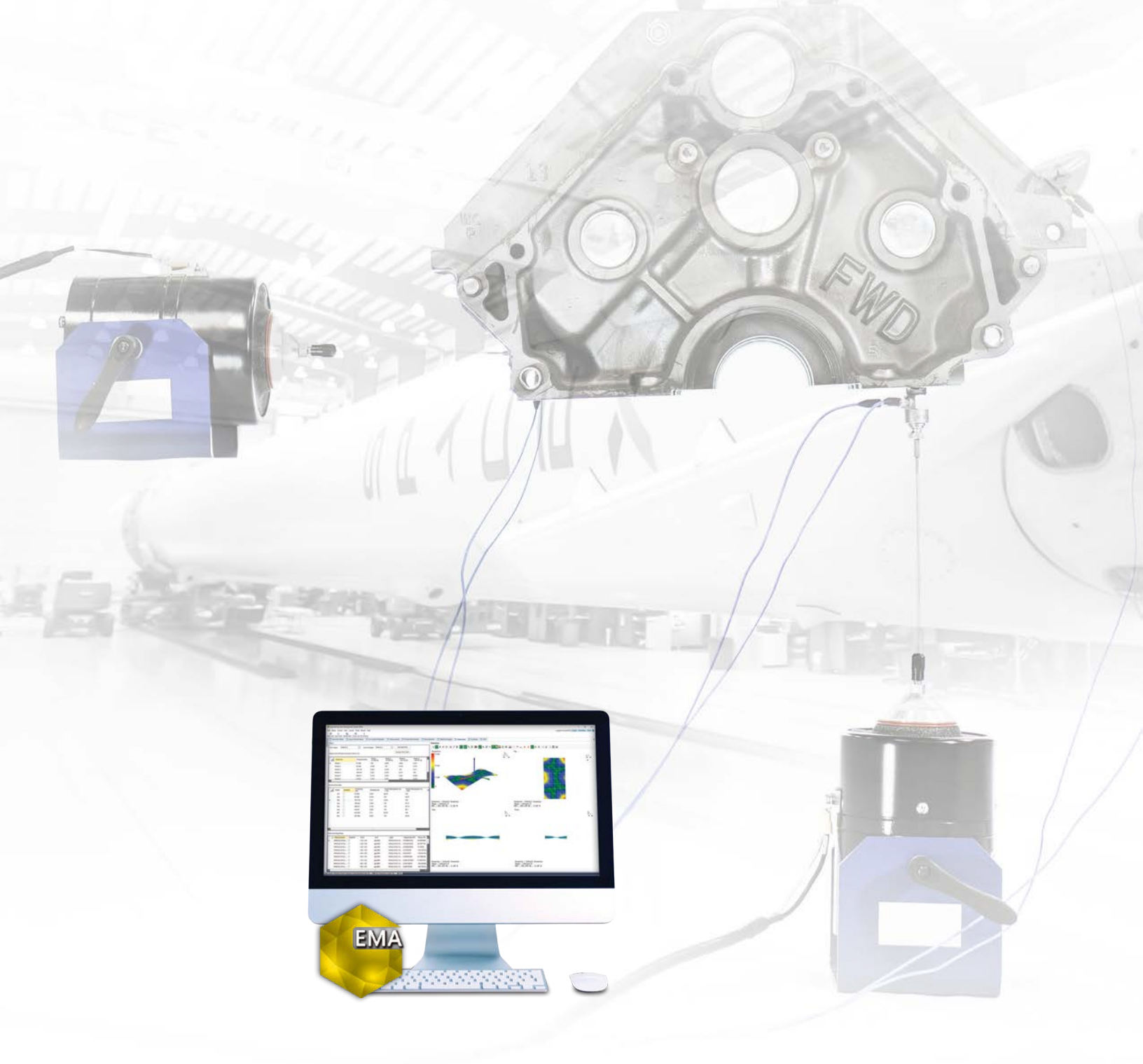


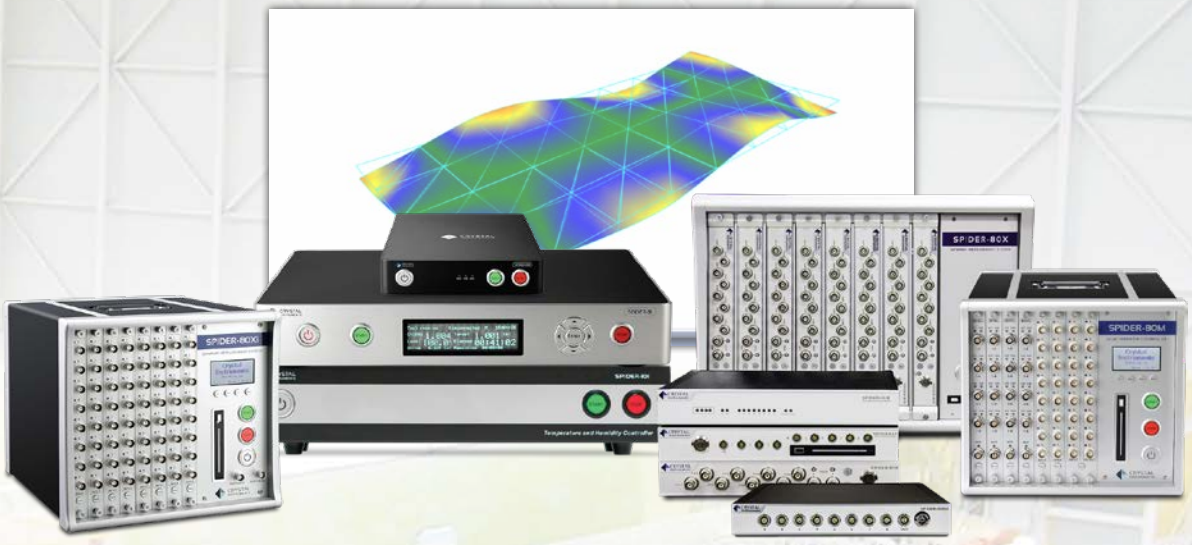

## Overview

Engineering Data Management (EDM) is a PC-based software program designed for real-time data management and processing. This intuitive Windows-native software manages the communication between PCs and all Crystal Instruments hardware platforms.

EDM Modal is a complete Modal Testing and Analysis suite for Experimental Modal Analysis (EMA). EDM Modal was developed based upon the sophisticated technologies of modern modal analysis theory and technique. With its intuitive controls and powerful features, EDM Modal is the ultimate tool for modal analysis applications. An intuitive interface allows users to manage highly complicated tests that can involve hundreds of measurement points and multiple excitations. This interface enables users to conduct simple tests quickly and with minimal effort. Regardless of how complicated the modal test is, EDM Modal provides the exact and most precise tools to achieve your goals.

To successfully acquire testing data, it is essential to properly book-keep the Degree-of-Freedoms (DOFs) of the test structure. The Geometry Editor handles all types of structure modeling and supports all types of coordinate systems. Using the concept of ‘components’, parts of a complicated structure are built simply and then integrated into the geometric model. Users can define the measurement points and their corresponding directions inside the Input Channel Setup window. Once the test is started, the measurements will proceed through all the test points, as defined by the Degree-of-Freedom (DOF) information for each measurement point.

To acquire the FRF signals, there are several methods per excitation arrangement. The usual methods involve measuring the excitation along with the response signals. Included methods are hammer impact testing or modal shaker(s) testing. Choose random or sine for the drive signal when using a modal shaker. Under certain circumstances, the excitation is not available or difficult to measure. In these cases, apply the response-only modal testing method or Operational Modal Analysis to take use of the ambient excitation or machinery operating status.



*Crystal Instruments Spider Vibration Control Systems - Scale up to 512 Channels*

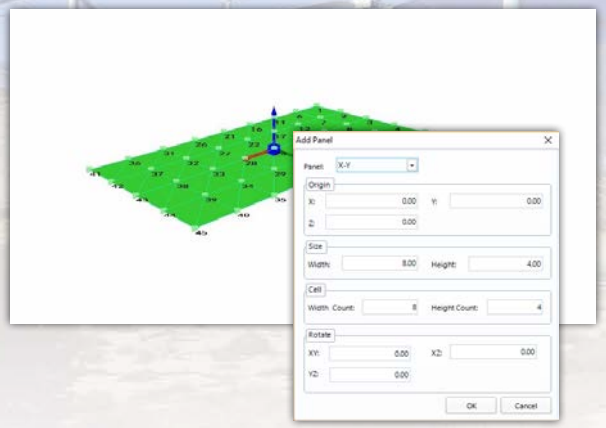
## EDM MODAL SOFTWARE

### Supports the Following Applications:

- Geometry Creation/Import/Export/Animation
- Operational Deflection Shape analysis
- Supports **Spider Systems** with up to 512 input channels
- Impact hammer modal testing
- Single or multiple shaker modal testing
- Single-Input Multiple-Output swept sine modal testing
- Single-Input Multiple-Output stepped sine modal testing
- Multiple-Input Multiple-Output stepped sine modal testing
- Operational Modal testing and analysis
- Single reference modal analysis
- Poly-reference modal analysis
- **Poly-X** (p-LSCF) modal analysis
- Measurement data review
- Reports export to Microsoft Word

Modal parameter identification is at the heart of modal analysis. EDM Modal employs several curve fitting methods for modal parameter identification. The Least-Squares Complex Exponential (LSCE) method is implemented for the pole (natural frequency and damping factor) identification of single-reference Frequency Response Function (FRF) cases. For multiple-reference (Multiple Input/Multiple Output or MIMO) testing cases, the corresponding Poly-Reference Time Domain (PTD) method is an applicable option. Users can isolate closely-coupled modes using the Modal Participation Factor (MPF) from multiple reference FRF data. For mode shape calculation, the renowned and intuitive Poly-Reference Frequency Domain method (PFD) is used.

The animation tool is a powerful visualization facility that simulates the mode shapes of the device under test, allowing users to study and understand large amounts of data through a three-dimensional animated display. The animation module can apply color contours to the surfaces of the geometry model further enhance visualize deflections in a three-dimensional space. Free-form Deformation (FFD) enhances the mode shape animation, resulting in smoother and more realistic mode shape displays. Utilize the same geometry model to display Operational Deflection Shapes (ODS) using measured time or spectrum operating responses.




## GEOMETRY

### Features:

- Basic elements: point, line, surface; editing graphically or through editor table entry
- Coordinate system: Cartesian, Cylindrical, Spherical
- Component entry: origin, direction (Euler angle)
- Built-in component library: line, plane, cube, sphere, cylinder and circle
- Geometry model Save/Open/Clear
- Geometry model import: UFF (.unv), CAD (.dxf, .stl, .obj, .3ds), Nastran (.nas), and .xml
- Imported geometry model decimation
- Geometry model display: point, line, surface; point directions, point number; surface norm; origin
- Geometry view: Perspective, Quad (perspective, Top, Side, Front)

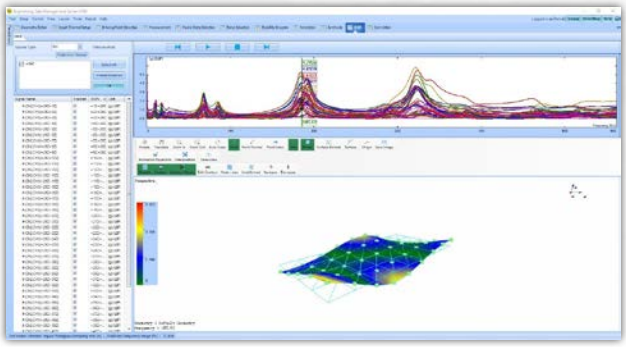
### Geometry

EDM Modal Geometry/ODS/Animation is an essential EDM Modal software module and is required for every EDM Modal system. This option provides fast and efficient structural model generation and full 3D visualizations of test and analysis results.

Users can add or delete the base elements (points, lines, and surfaces) on the graphic interface or type commands into the Model Editor. Users can specify components for each part of the structure. Each component can have its own origin, directions, and Euler angles. The basic component library includes: line, plane, cube, cylinder, sphere and circle. Users can add any of these components to the geometry model by specifying the origin, direction, dimensions, and number of cells of the component.

Users can save and recall the geometry model later through other tests. Easily clear or keep the model when starting over with a new geometry model for the structure under a current test. Several types of formats from third party applications are supported for geometry model import. Users can import the widely used Universal File Format (UFF) format of point and line models to EDM Modal Geometry.

One of the most used features of EDM Modal Geometry is mode shape animation. Users can select from several types of animation such as ‘point and arrow’, wireframe, or surface contour. The animation view mode options are Single Perspective View or Quad-View (Perspective/Top/Side/Front). Users can save each cycle of mode animation as an .avi file.



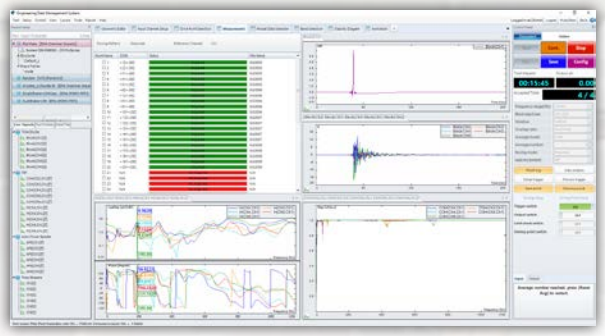
## Operational Deflection Shape

EDM Modal Operational Deflection Shape (ODS) provides users with a superior visualization of the deformation in the structure under test. The EDM Geometry Model animation feature provides animations of time domain data and spectrum data. It is an integrated feature of EDM Modal Geometry and is compatible with all EDM Modal software modules.

The database structure of EDM allows users to easily navigate through and select data. Users can animate the selected data set using the geometry model. Users can save the vibration pattern (either in time domain, or frequency domain) to .avi video files as well.

**Features:**

- Data management of time domain and frequency domain
- Supported time data: block, recorded time data
- Animation of 3D geometry model with frame or contour
- Animation equation editor and animation with interpolation
- Animation amplitude control
- Animation video file saving



## HAMMER IMPACT TESTING

**Features:**

- Intuitive, easy-to-use testing process
- Geometry based testing process
- Roving hammer or response
- Auto or manual Point/Direction increment
- Manual/Auto trigger arming
- Resizable preview window for DOFs, frame counts, impact/response waveforms
- Double hit detection on/off, auto/manual reject
- Driving point selection
- Audio/graphic feedback of test status
- H1, H2, H3, and Hv estimation
- Acquired, in progress, not acquired list of tables for all DOFs

### Hammer Impact Testing

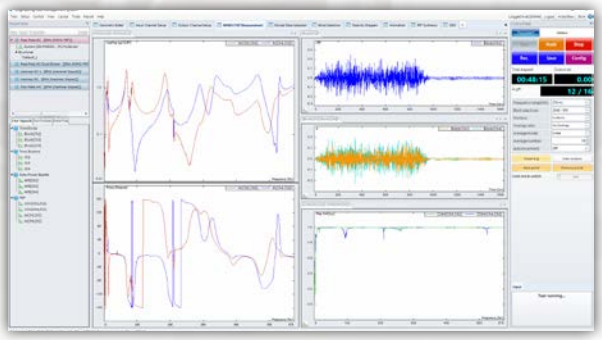
EDM Modal Hammer Impact Testing provides the necessary features for a single-operator experimental modal test. The Hammer Impact GUI features an intuitive step-by-step process, allowing a user to easily go through set-up and testing.

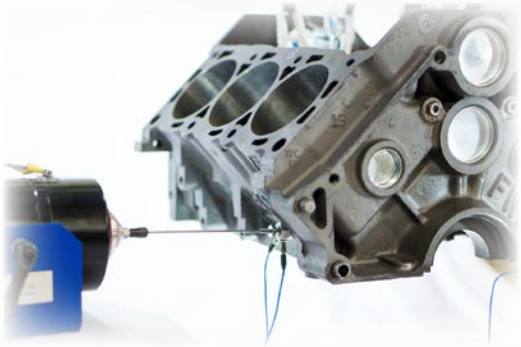
The testing process is designed to help users quickly define acquisition parameters, thus providing more time for analysis. Users can define trigger behavior through the Trigger Setup. A Trigger-Preview window allows control over the trigger level and pre-trigger delay. For users that may need to review their measurements after each acquired frame, the 'Manual-Arm' trigger mode is available. When this trigger mode is selected, acquired signals will be displayed for review and will prompt the user to accept/reject the signal. The auto-arm mode simply auto-accepts acquired measurements and automatically re-arms the trigger, helping to speed up the whole test process.

Another implemented feature is Driving Point Selection, which helps users decide where to place the fixed excitation or response reference. The idea here is to survey several candidate driving-points and measure their FRFs – which allows users to choose the best available DOF for the driving point. Select the FRF at the trial driving-point that effectively excites most of modes as the driving-point. EDM simplifies the data management for this important pre-test survey.

When taking measurements, the status of the DOFs are indicated in a table window. The status of every measurement point is available from this table, which is updated as the test progresses. The Trigger Preview window is optimized for your viewing experiences – featuring a resizable window and adjustable font size. The font size increases when the window itself is dragged to be enlarged. With the added flexibility of the trigger window, EDM Modal supports users with various display types – allowing users to take measurements at a long distance from the display. Users have complete control of their testing, regardless of how far they are located from the computer.

One common problem associated with hammer testing is the "double hit". EDM Modal Hammer Impact software can automatically detect a double hit and provides users with an option to automatically or manually reject the double strike. Hammer impact testing is seamlessly integrated with the necessary post modal analysis inside the EDM software.





## Single-Input Multiple-Output (SIMO) FRF Testing

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), users can set the delay block and cyclic block numbers 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 MIMO FRF testing.

**Features:**

- Intuitive, easy-to-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

## MULTIPLE INPUT MULTIPLE OUTPUT (MIMO) FRF TESTING

**Features:**

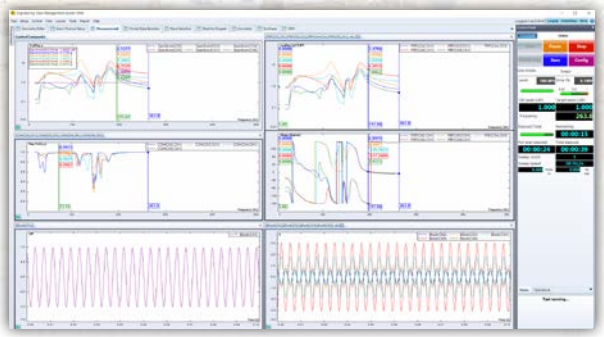
- Intuitive, easy-to-use testing process
- Point/direction auto/manual increment
- Synchronized outputs
- One or multiple excitation (reference)
- Source trigger mode for synchronized acquisition and source excitation
- Random, burst random, pseudo random, period random, chirp/burst chirp output types
- 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

### Multiple-Input Multiple-Output (MIMO) FRF Testing

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 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), users can set the delay block and cyclic block numbers so that the structure exhibits a steady-state response, allowing for 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, users can simultaneously measure multiple columns of the Frequency Response Matrix. When combined with the poly-reference curve fitting algorithm, the modal participation factor will help in isolating repeated and highly coupled modes.



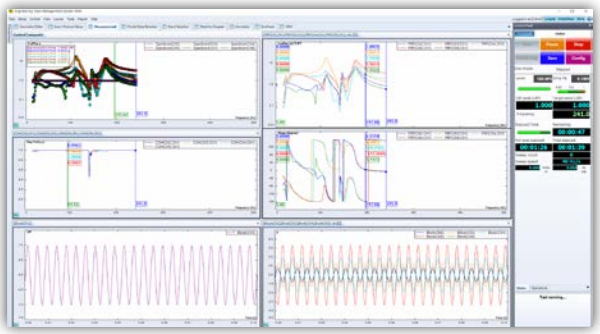
## Single-Input Multiple-Output (SIMO) Swept Sine Testing

EDM Modal SIMO Swept Sine testing includes a dedicated test setup and operation process flow using a single shaker outputting a sine wave to acquire FRF signals. The source output type is swept 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. Users can define the output drive level to run the test under no control strategy or run the test in a closed loop by specifying the response of a control channel.

The modal analysis process is seamlessly integrated with SIMO Swept Sine testing.

**Features:**

- Intuitive, easy-to-use testing process
- Point/direction auto/manual increment
- One swept sine excitation (reference)
- 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 left/start/end frequency; sweep speed



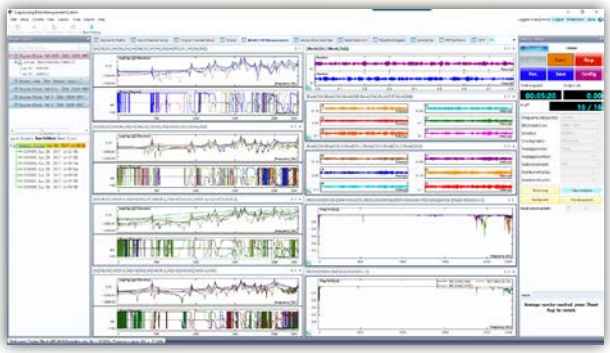
## Single-Input Multiple-Output (SIMO) Stepped Sine Testing

EDM Modal SIMO Stepped Sine testing includes a dedicated test setup and operation process flow using a single shaker outputting a sine wave to acquire FRF signals. The source output type is either swept sine or stepped sine. The sweep or step mode can be linear or logarithmic. The FRF signals of each measurement DOFs with respect to a defined reference channel will be constructed. Users can define the output drive level to operate the test in an open loop. To operate the test in a closed loop, users can define the response of a control channel.

The modal analysis process is seamlessly integrated with SIMO Sine Swept Sine testing.

**Features:**

- Intuitive, easy-to-use testing process
- Point/direction, auto/manual increment
- One sine excitation with single tone (reference)
- 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); transition speed



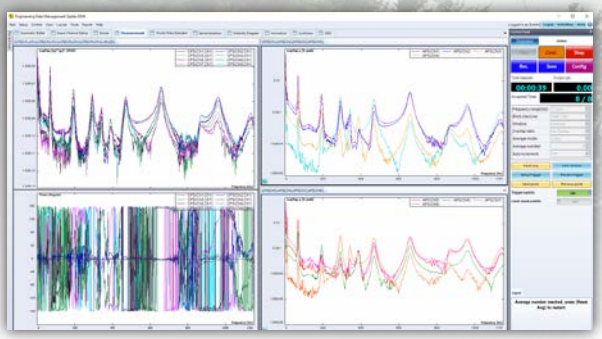
## Multiple-Input Multiple-Output (MIMO) Stepped Sine Testing

EDM Modal MIMO Stepped Sine testing includes a dedicated test setup and operation process flow using multiple shakers outputting sine waves to acquire FRF signals. The source output type is stepped sine tones. The step mode can be linear or logarithmic. The FRF signals of each measurement DOFs with respect to defined reference channels will be constructed. Users can define the output drive level to operate the test in an open loop. To operate the test in a closed loop, users can define the response of a control channel.

The modal analysis process is seamlessly integrated with MIMO Sine Swept Sine testing.

**Features:**

- Intuitive, easy-to-use testing process
- Point/direction auto/manual increment
- Multiple sine excitation with sine tone (references)
- Multiple number of sweeps
- Different initial phase conditions for each sweep: +/- or random
- Specify source output level profiles; or control the amplitude of input channels
- Linear, Logarithmic sweep mode
- Filter, RMS, Mean or Peak for measurement strategy
- Fixed or proportional tracking filter, with user defined band-width
- User defined Start/end frequency; Number of points; Delta F (or Points/Oct); Transition speed



## OPERATIONAL MODAL ANALYSIS

**Features:**

- Intuitive, easy-to-use testing process
- Point/direction auto/manual increment
- User defined reference channel
- Scope tab to view channel data before measurement
- Expanded cross power spectrum for all input channel vs. reference channel
- Cross power spectrum vector(S) smoothing, multiple times or cancel

### Operational Modal Testing

EDM Modal Operational Modal Testing (OMA Testing) includes a dedicated test setup and operation process flow using ambient vibration data. Using a large channel count data acquisition system (e.g., Spider-80X or Spider-80Xi), the excitation method provides a much higher efficiency and accuracy for FRF measurements while minimizing local stresses on the test article.

Typical modal analysis methods and procedures are based on forced excitation tests carried out in the laboratory. Frequency Response Functions (FRFs) are measured as input to modal parameter identification. However, the real loading conditions to which a structure is subjected often differs considerably from those used in a laboratory testing. In many cases, (i.e., excitation of off-shore platforms or traffic/wind excitation of a bridge,) forced excitation tests are very difficult, if not impossible to conduct; at least when using standard testing equipment. In such cases, operational vibration data is often the only resource available.

Operational modal testing is designed to measure and process ambient vibration response data, which will be ready for parameter identification. The resulting cross power spectrum vector(s) can be further smoothed by using the de-convolution method.

The modal analysis process is seamlessly integrated with Operational Modal testing.

## STANDARD MODAL ANALYSIS

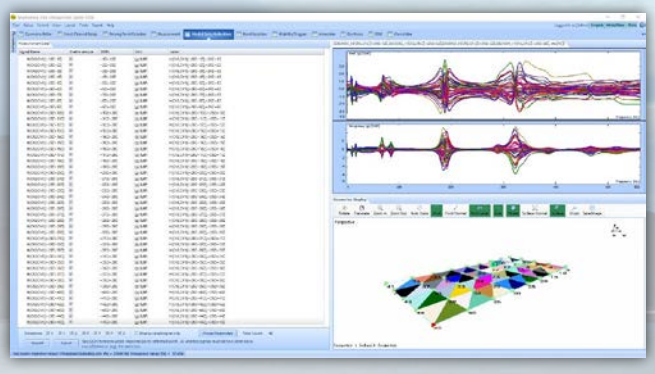
**Features:**

- Easy-to-use modal data selection
- Signal Smoothing with Deconvolution (for OMA testing only)
- MIF: Multivariate MIF, Complex MIF, Real MIF, Imag sum MIF
- User selectable frequency band for parameter identification
- Stability Diagram
- Proven curve fitting method: LSCE
- 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
- Node lines
- 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

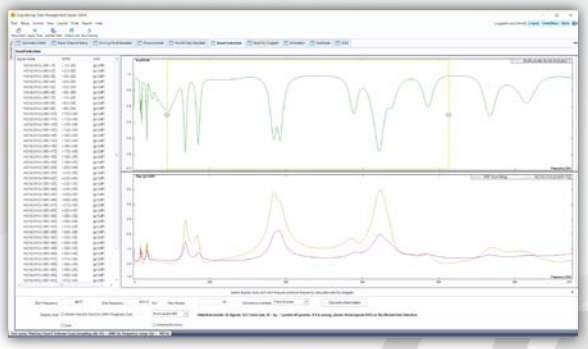
### Standard Modal Analysis

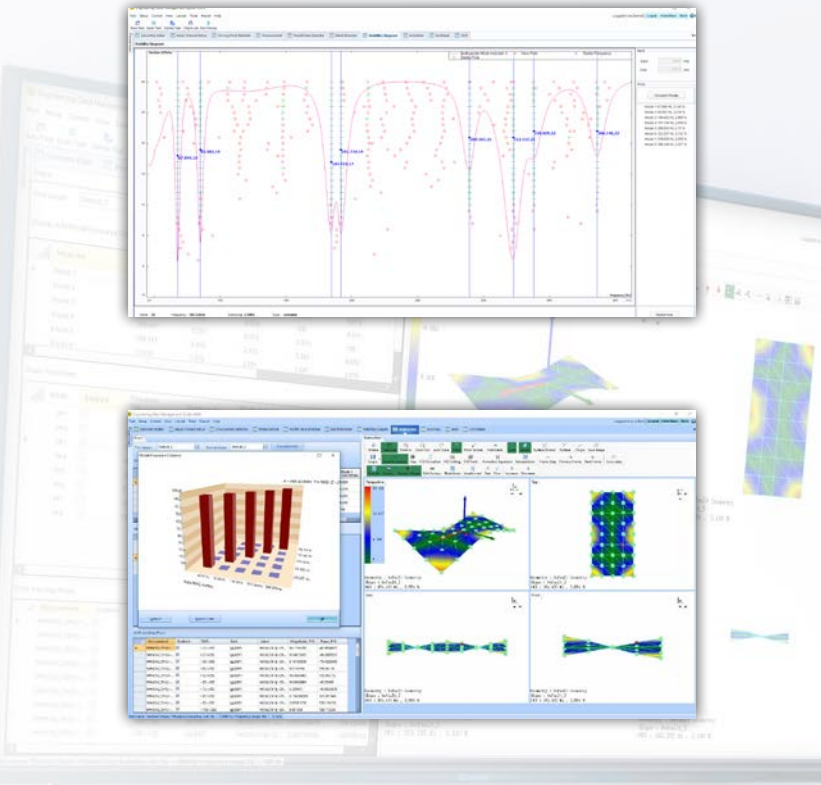
EDM Modal Standard Modal Analysis provides the user with a complete arsenal of tools, from FRF data selection and parameter identification to results validation and mode shape animation.

Upon completion of Modal testing, the resulting set of FRF data is made available for the next step: Modal Analysis. Users can also add/replace individual FRF signals. The complete set of FRF test signals can be exported or imported from other sources. These operations are managed by 'Modal Data Selection'. The FRF signals are organized one by one or in multiples on one window display for a rapid comprehensive review.



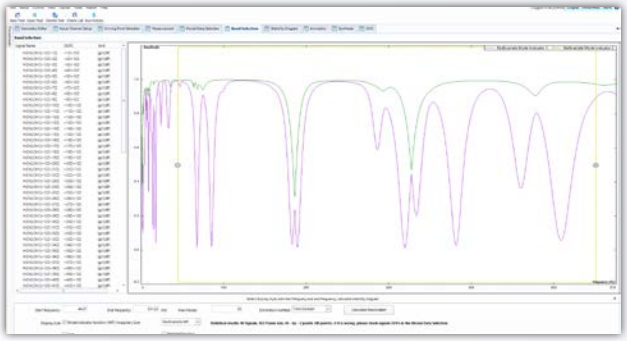
With one click, the Modal Parameter Identification process is started. Users can label the natural frequencies with the assistance of the Mode Indicator Function (MIF). The Multivariate, Complex, Real, and Imaginary Sum MIFs are available. MIF indicators aide in identifying repeated roots (repeated poles) and closely-spaced distinct roots.





A Stability Diagram is employed with modal parameter identification. With the Standard Modal Analysis option, the proven Least Square Complex Exponential (LSCE) fitter is implemented for pole identification. The physical poles sought are stable (as opposed to 'computational poles' sometimes produced by the LSCE) and can be selected from the Stability Diagram for the next step mode shape calculation, using the Least Square Frequency Domain (LSFD) algorithm.

The resulting mode shape table can be saved and used for mode shape animation. Modal Assurance Criterion (MAC) function and FRF synthesis are also available. These provide means for modal parameter validation.



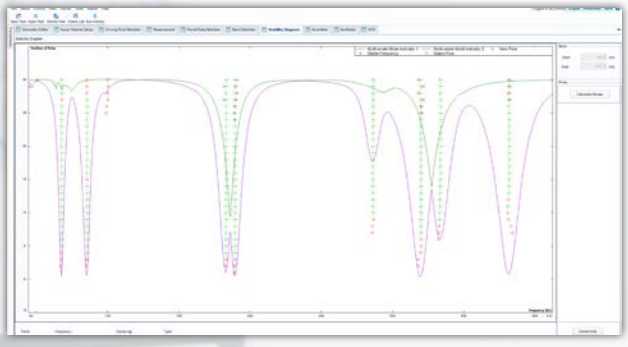
## Advanced Modal Analysis

EDM Modal Advanced Modal Analysis includes all the features of Standard Modal Analysis in addition to providing the Poly-reference modal analysis algorithm to curve fit the FRF matrix from the MIMO FRF testing results. The time domain curve fitting algorithm utilized for pole identification is the sophisticated and proven Poly-reference time domain method (PTD).

The selection of the curve fitting method, PTD or LSCE, is automatically based on the type of FRF signal set selected, whether it is single reference or multi-reference.

**Features:**

- Includes all features of Standard Modal Analysis
- Poly-reference time domain (PTD) curve fitting
- Auto selection of curve fitter per single or multiple reference from the FRF data set



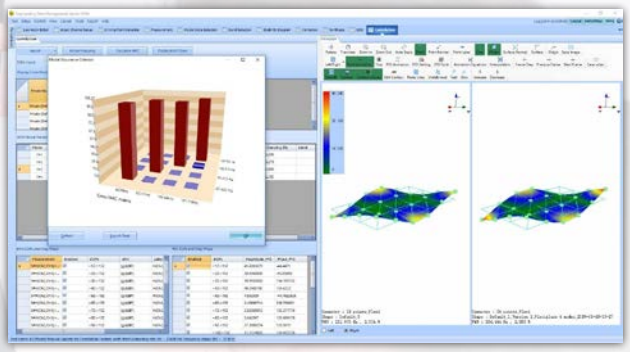
## Premium Modal Analysis

EDM Modal Premium Modal Analysis includes all the features of Standard and Advanced Modal Analysis as well as Poly-X (the poly reference Least Square Complex Frequency domain (p-LSCF) modal analysis algorithm to curve fit the FRF matrix from the MIMO FRF testing results. The frequency domain modal parameter estimator is more efficient and neatly displayed on the stability diagram.

The selection of the curve fitting method (Time Domain or Poly-X) is available in EDM Modal software. It applies to either single reference or poly-reference FRF data sets.

**Features:**

- Includes all features of Standard and Advanced Modal Analysis, plus,
- Poly-X: Poly-reference Least Square Frequency Domain (p-LSCF) curve fitting
- Neatly displayed stability diagram with emphasis on stable poles



## Correlation Analysis

EDM Modal Correlation Analysis allows the user to correlate two modal models; EMA and/or FEA models. Comparing the experimental data with that acquired through finite element analysis helps in validating the test results. Users can import the geometry model and mode shape data from FEA or EMA software. 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 the two methods, a Cross-MAC matrix is calculated and shown.

**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

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2370 OWEN STREET
SANTA CLARA, CA 95054 (USA)
PHONE: +1-408-986-8880
FAX: +1-408-834-7818
EMAIL: INFO@GO-CI.COM
WWW.CRYSTALINSTRUMENTS.COM