Uses and Features

**Uses**
- Single and polyreference classical modal analysis from measured frequency response functions (FRFs)
- Estimation of modal parameters to be used for finite element (FE) model correlation and updating, design verification, benchmarking, quality control and troubleshooting
- Test planning using finite element analysis (FEA) results
- Integrated solutions together with the following software:
  - From measurement to FEM correlation: With PULSE Reflex Structural Measurements Type 8729-B and PULSE Reflex Correlation Analysis Type 8722
  - From measurement to analysis: With PULSE Reflex Structural Measurements Type 8729-B or PULSE Modal Test Consultant Type 7753
- Open, stand-alone application with your existing data acquisition system

**Features**
- Efficient workflow with just a few steps to perform a complete modal analysis
- Quick searching, sorting and filtering of large amounts of data
- Easy-to-use and powerful geometry drawing tools using built-in CAD models
- Import of geometry in standard formats, including FE models
- Animation of FE models for test planning and validation
- Selection and validation of test nodes from FE models for test planning
- Decimation of FE models to test models
- Display of selected FRFs from excitation/response DOFs on geometry
- Function-based animation for validation of test setup
- Normal mode indicator function (NMIF), power mode indicator function (PMIF), complex mode indicator function (CMIF), multivariate mode indicator function (MMIF)
- SDOF curve-fitters: Least squares global partial fraction and quadrature picking
- MDOF curve-fitters: Rational fraction polynomial-Z, polyreference frequency, polyreference time, eigensystem realization and alias-free polyreference
- Global solve curve-fitters for modal parameter estimation in cases of consistent FRF data
- Local solve curve-fitters for modal parameter estimation in cases of inconsistent FRF data
- Clear stability diagrams for improved overview and straightforward mode selection
- Enhanced mode solution for clear stability diagrams
- Cluster diagrams and pole density diagrams for optimal curve-fitting and mode selection
- Automated mode selection using your preferred curve-fitter
- FRF synthesis including error function and frequency response assurance criteria (FRAC)
- Complexity plots, AutoMAC and CrossMAC tables and 3D plots for validation of mode shape complexity and correlation
- CoMAC geometry plots for comparing paired modal models
- Integrated Microsoft® Office reporting capabilities
PULSE Reflex is the latest addition to the PULSE platform of software products. It provides real-time measurements, analysis and test-FEA integration in a modern, intuitive GUI environment and is the culmination of extensive customer surveys to resolve their most important issues when analysing sound and vibration data.

PULSE Reflex provides:
- Enhanced usability for high productivity with an intuitive user interface that puts the tools you need at your fingertips. The graphical user interface is built around a workflow model that leads you easily through any test setup, measurement and analysis process
- Open data policy that supports a wide range of native and third party formats for improved import and export of data
- Consistent user interface throughout all applications encouraging faster learning of new applications

PULSE Reflex Structural Dynamics allows you to observe, analyse and document the dynamic behaviour of structures using a single software platform covering setup, measurements, analysis and test-FEA integration. With PULSE Reflex Structural Measurements, you can set up and perform single or poly-reference hammer and shaker measurements, whereas PULSE Reflex Modal Analysis provides accurate and reliable results even in the most demanding situations using a targeted set of best-in-class mode indicator functions, curve-fitters and analysis validation tools.

Reflex Correlation Analysis adds the capability of correlating two modal models, for example, finite element model versus test model using tools such as Geometry Alignment, CrossMAC and Cross-orthogonality calculations.

The open data policy behind the PULSE Reflex Structural Dynamics suite also allows the post-processing applications to be used as stand-alone applications together with your existing measurement and analysis system.

Measurement and Integration

PULSE Reflex Structural Measurements
PULSE Reflex Structural Measurements Type 8729-B contains tasks for setup and measurement to perform hammer and shaker testing. The tasks are fully embedded into PULSE Reflex Modal Analysis — creating a single application for modal setup, measurement and analysis. Measurement setup, execution and validation can be performed manually, table-based or geometry-guided.
**PULSE Modal Test Consultant**

PULSE Reflex Modal Analysis also seamlessly integrates with PULSE Modal Test Consultant (MTC) creating a highly consolidated solution for modal data acquisition and analysis. PULSE MTC supports geometry-guided hammer and shaker testing and exports the geometry and measurement data to PULSE Reflex Modal Analysis.

**Support for Other Systems**

The open data policy behind the PULSE Reflex Structural Dynamics suite also allows each application to be used as stand-alone applications together with your existing measurement and analysis system.

**Geometry Creation, Import and Decimation**

With PULSE Reflex Modal Analysis, geometries can be created from scratch using the embedded drawing tools. You can work with various elements like points, lines, triangular or quad surfaces and you can create 2D and 3D CAD models and mesh them. The geometry can also be created from table entries.

Alternatively, import a geometry in standard data formats like UFF and CSV. Measurement DOFs contained in the imported measurement files are automatically added to and shown on the geometry in subsequent tasks.

Finite element (FE) models can be imported and used in PULSE Reflex Modal Analysis for test planning and validation.

*• Animate FE models to investigate frequency range of interest, mode density/order, critical modes, etc.*

*• Based on the animations, select optimal excitation and response locations for modal testing*

*• Select test node locations on an FE model until a satisfactory finite element AutoMAC is created*

*• Decimate FE models to test models for modal testing*

*• Compare test results with FEA results*

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**Fig. 2**

Geometry Editor. Geometries can be created using basic drawing elements, meshed CAD models or in tabular form.
Selecting nodes on a FE model helps determine which nodes on the FE model to include in a test geometry to identify and separate the modes of interest. The geometry with highlighted nodes is automatically loaded into the Geometry Decimation task for connecting the selected nodes with tracelines and/or elements.

Analysis and Reporting

By logically grouping features and display of results, PULSE Reflex Modal Analysis allows you to do a complete modal analysis in just four main steps:

- Measurement Validation
- Parameter Estimation Setup
- Mode Selection
- Analysis Validation

In addition, a User Defined Layouts task is available, and extensive live reporting can be done in Microsoft® Word, Excel® or PowerPoint® at any time in the analysis using integrated reporting functions.

Measurement Validation
The Measurement Validation task is used to check the quality of the measurement data prior to performing the modal parameter extraction. Functions like ordinary and multiple coherence, reciprocity and driving point FRFs, or all FRFs from selected references can easily be shown by simply dragging the functions from the Project Browser.

The Geometry Driven Function Display provides a graphical tool that allows you to select on the geometry the DOFs that are to be used for the displayed function types. Data can also be sorted and filtered in a table to easily select individual functions to be displayed.
Fig. 4  
Measurement Validation.  
In the Geometry Driven Function Display, functions are selected by clicking on the desired excitation and response DOFs on the geometry. In this example, the FRFs are those related to the shaker at the front. You can easily scroll up and down to view all selected FRFs related to this shaker.

For validation of test setups, such as identifying cable breaks and faulty and incorrectly mounted transducers, animations can be done based on FRFs. For structures with lightly damped and well-separated modes, the FRF shapes will resemble mode shapes.

Operating deflection shapes (ODS) from phase-assigned spectra can also be shown and saved, for example, to compare with mode shapes.

Parameter Estimation Setup
The Parameter Estimation Setup task is where you prepare and execute the curve-fitting. FRF data to include in the analysis are easily filtered, sorted and then selected using the Data Matrix Selector table. In the same screen layout, the geometry with DOF information is shown together with a graph area for investigating potential modes using different mode indicator functions. Various SDOF and MDOF curve-fitters can be selected and the frequency range of interest can be set, including the time range, when using time domain curve-fitters. Both global and local solve curve-fitters are available.

Previews of the stability diagram for the different curve-fitters aid in the selection of the preferred curve-fitter for the task. To assist in this, powerful tools like cluster diagrams and pole density plots are also available.

The unique enhanced mode solution algorithm provides very clear stability diagrams, making it easy to discriminate true physical modes from non-physical modes.

Fig. 5  
Parameter Estimation Setup. Prepare and preview curve-fitting. This example shows the CMIF.
The powerful set of mode indicator functions and curve-fitters gives you the best possible tools in any given situation whether weakly excited modes, heavily damped modes, repeated roots or inconsistent FRF data are present.

**Mode Selection**

In the Mode Selection task, the modal results are shown in terms of natural frequency, damping ratio, mode shape animation and synthesis of FRFs. Once a mode is selected using one of the stability diagrams (with MDOF curve-fitters) or FRFs (with SDOF curve-fitters), it will immediately show up in the Mode Table, the mode will be animated and the synthesized FRFs will be compared to the measured ones.

![Fig. 6](image)

Mode Selection. Modes selected are shown in the mode table, animated, and the FRFs synthesized. In this example, automated mode selection was applied. The enhanced mode solution algorithm provides clear stability diagrams.

Automated mode selection is supported for fast preliminary investigations of unknown structures or when conducting repetitive testing. It also eliminates the potential risk of user-dependent results. Automated mode selection works for all MDOF curve-fitters by indicating the modes in the stability diagrams, populating the Mode Table, animating the first mode and showing the synthesis functions.

The Mode Selection task provides full flexibility for selection and comparison of modes from different curve-fitting methods for creation of the best possible modal model.

**Analysis Validation**

The Analysis Validation task supplies you with a number of tools for further investigation of the obtained modal results for maximum confidence in your obtained modal model. This includes FRF Synthesis, Mode Shape Animation, AutoMAC and CrossMAC tables and 3D plots, CoMAC geometry plots and Complexity plots. Modes can be normalized to non-complex values (normal modes) for comparison with real-valued FE modes.
Fig. 7
Analysis Validation. Side-by-side animation of first torsional and bending modes.

Fig. 8
Analysis Validation. CrossMAC comparing the mode shapes found using the Rational Fraction Polynomial-Z and Polyreference Time curve-fitters. The mode pair selected is automatically animated.

The Analysis Validation task can also be used to animate FE models for test planning or validation.

Fig. 9
Quad View colour contour animation of two mode shapes from a MSC Nastran™ FE model with more than 1 million nodes.
**Reporting**

The Report task enables reports to be prepared in parallel with the analysis process, linking important results as they are produced. Store geometries, displays, tables and text in the Project Browser as report elements and generate the report when you are ready. Reports can be based on standard embedded or customized templates you define, or on-the-spot. High-quality, active or static reports are easily created directly in Microsoft® Word, Excel® or PowerPoint®.

**User-defined Layouts**

The User Defined Layouts task enables you to create customized layouts consisting of graphs, geometries (with or without animation), shape tables, MAC tables/plots and complexity plots. Data can be linked between displays in the layout so that source data in one display is reflected in a result display. For example, when linking a mode table to a geometry, changes to the mode table will be automatically updated in the geometry. This allows for fast and flexible data viewing and ad hoc analysis.

**Product Structure**

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**Fig. 10**

PULSE structural dynamics product structure – from modal measurements to analysis and test-FEA integration. Real-time measurements can be performed in the PULSE LabShop environment (left), or completely integrated in the PULSE Reflex environment (right).

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**PULSE Reflex Base Type 8700**

PULSE Reflex Base provides the framework, including Project Browser, Reporting, Notes and Help system. The Base module must be installed to run any PULSE Reflex application.

**PULSE Reflex Measurements Type 8729**

**Spectral Analysis Type 8729-A**

This is the prerequisite for measurements in PULSE Reflex. It provides the Hardware Matrix, the Hardware Setup Table and the Level Meter as well as the Transducer Manager and the Transducer Verification tasks.

**Structural Measurements – Hammer and Shaker Type 8729-B**

Structural Measurements adds dedicated setup and measurements tasks for hammer and shaker testing, including measurements for MIMO analysis. Geometry-guided measurement setup, execution and validation is supported.
**Structural Measurements – Stepped Sine Type 8729-C**

Type 8729-C adds dedicated setup and measurement tasks for single and multi-shaker stepped sine testing. Geometry-guided measurement setup, execution and validation is supported.

For information on PULSE Reflex Measurements, see Product Data BP 2518.

**Geometry Type 8719**

Geometry allows the importation and creation of geometries and is used across the various PULSE Reflex Structural Dynamics solutions. FE models can be imported using UFF, and decimated to test models.

A variety of animation types are supported including wire frame, surface contour, point and arrow animation as well as overlaid, difference, top-bottom and side-by-side animation in single, dual or quad view format. The animations can be recorded as AVIs and included in Word and PowerPoint® reports.

**FE Interfaces Type 8718**

FE Interfaces enables you to import FE models from Nastran™, ANSYS® and ABAQUS®. For more information, see Product Data BP 2395.

**Modal Analysis Type 8720**

An application designed for single-reference modal analysis with a basic, yet comprehensive, set of mode indicator functions (MIFs), curve-fitters and analysis validation tools. For use with single shaker FRF data and single reference hammer testing data.

Modal Analysis includes:
- Mode indicator functions: Normal MIF (NMIF) and Power MIF (PMIF)
- Curve-fitting:
  - SDOF: Least Squares Global Partial Fraction, Quadrature Picking
  - MDOF: Polyreference Time, Polyreference Frequency – limited to one reference
  - Global solve curve-fitting
  - Local solve curve-fitting (Polyreference Time)
  - Stability diagram with Enhanced Mode Solution (Polyreference Time)
  - Automated mode selection
- Analysis validation: AutoMAC and CrossMAC

**Advanced Modal Analysis Type 8721**

Advanced Modal Analysis adds polyreference modal analysis capabilities and advanced MIFs, curve-fitters and analysis validation tools to the Modal Analysis application. For use with shaker MIMO (Multiple Input Multiple Output) FRF data, polyreference hammer testing data or for advanced analysis and validation of both single and polyreference data.

Advanced Modal Analysis adds:
- Geometry Node Selection task
- Mode indicator functions: Complex MIF (CMIF) and Multi-variate MIF (MMIF)
- Curve-fitting:
  - MDOF Curve-fitters: Polyreference Time and Polyreference Frequency (no reference limitations), Rational Fraction Polynomial-Z (RFP-Z), Eigensystem Realization and Alias-Free Polyreference (AFPoly™)
  - Local solve curve-fitting (RFP-Z)
  - Stability diagram with Enhanced Mode Solution (RFP-Z)
  - Advanced stabilization diagrams: Cluster diagram and Pole Density plot
- Analysis validation: Complexity plot and CoMAC geometry plot

**ODS Analysis**

With licenses for Types 8700 and 8719 installed, a PULSE Reflex ODS Analysis application is available for frequency-based spectral ODS post-processing analysis or for viewing modal analysis results.

**Correlation Analysis Type 8722**

Correlation Analysis adds the ability to correlate two modal models: FEM vs Test, Test vs Test or FEM vs FEM. For more information, see Product Data BP 2395.
SOFTWARE REQUIREMENTS
This supports FEM import, visualization and animation of models up to Intel® Core™ i7, 3 GHz or better with 16 GB RAM or more.

RECOMMENDED PC FOR USE WITH FE MODELS
- Geometries based on built-in CAD models:
  - Basic geometries using nodes, tracelines, triangle and quad elements
- GEOMETRY CREATION AND EDITING
  - Decimation
  - Geometry Creation, Import, Node Selection and
    - Test for I-deas data: Function (.afu) and shape (.ash) files
  - Standard measurement data formats: UFF type 58 (Binary & ASCII),
    - Measurement data and geometry seamlessly transferred from PULSE
    - Structural Measurements Type 8729-B: For hammer and shaker
      - Support of Cartesian, Cylindrical and Spherical coordinate systems.
    - Tables for Coordinate Systems, Nodes, Elements, Tracelines and
      - Tables for Coordinate Systems, Nodes, Elements, Tracelines and
    - Hierarchical geometry tree view with subfolders for Coordinate
      - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
    - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
- Other Modules
  - Visual link between selections in Geometry 3D View and Geometry Tree
  - Move (translate, rotate) and copy (linear, radial) operators for CAD
    - AutoMAC is created.
  - Select test node locations on a FE model until a satisfactory FE
    - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
    - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
- GEOMETRY NODE SELECTION
  - Geometries based on built-in CAD models:
    - Curves: Circle, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
    - Line, Polyline, Interpolation Spline and Control Points Spline
- Dynamic Point Numbering
  - Show more point numbers (IDs) when zooming in on parts of the
    - DYNAMIC POINT NUMBERING
      - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
      - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic,
GEOMETRY VIEWS
• Single, Side-by-Side, Top-Bottom and various Quad views
• Definition of front, back, left, right, top and bottom view axis
• Isometric view
• Perspective, orthographic and stretched projections of geometry
• Hidden lines and transparency
• Pan, zoom and rotate options for viewing geometries
• Symbols for shaker, impact hammer, force transducer and accelerometer positions shown on geometry with customized colours and sizes

CUTTING PLANES
Cut through a geometry in three user-definable 2D planes to view the interior or exclude viewing parts of the geometry – also during animation

ANIMATION
• Deformed and undeformed animation with Max. Deformation
• Single, overlaid and difference animation
• Wireframe, contour (solid/solid edge), points and arrow animation
• Animation of non-measured DOFs using interpolation equations
• AVI file generation with selectable codec

Measurement Validation
Geometry Driven Function Displays: Show FRFs based on selected excitation and response DOFs on the geometry
Function-based Animation: Animate geometry using, for example, FRFs or PAS (ODS). Saving of shapes in Shape Table

Parameter Estimation Setup
FUNCTION SELECTOR
Selection of FRF data to be included in curve-fitting

MODE INDICATOR FUNCTIONS
Modal Analysis: Normal Mode Indicator Function (NMIF) and Power Mode Indicator Function (PMIF)
Advanced Modal Analysis: Complex Mode Indicator Function (CMIF) and Multi-variate Mode Indicator Function (MMIF)

CURVE-FITTERS
Modal Analysis:
• SDOF: Least Squares Global Partial Fraction, Quadrature Picking
• MDOF: Polyreference Frequency and Polyreference Time (with single reference)
Advanced Modal Analysis: MDOF: Polyreference Frequency and Polyreference Time (with multiple references), Rational Fraction Polynomial-Z (RFP-Z), Eigensystem Realization, Alias-Free Polyreference (APoly)
Enhanced Mode Solution: Optimal clarity of the stability diagrams with Polyreference Time and RFP-Z

Solve Method:
• Global: All curve-fitters
• Local: Polyreference Time and RFP-Z

Mode Selection
Mode Selection: Manual or Automatic
Shape Types: Real or Complex
Table 1 Ordering information for PULSE Reflex Structural Dynamics suite software

<table>
<thead>
<tr>
<th>Item No.*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 8700-X</td>
<td>PULSE Reflex Base</td>
</tr>
<tr>
<td>Type 8718-A-X</td>
<td>PULSE Reflex Nastran Interface</td>
</tr>
<tr>
<td>Type 8718-B-X</td>
<td>PULSE Reflex ANSYS Interface</td>
</tr>
<tr>
<td>Type 8718-C-X</td>
<td>PULSE Reflex ABAQUS Interface</td>
</tr>
<tr>
<td>Type 8719-X</td>
<td>PULSE Reflex Geometry</td>
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<tr>
<td>Type 8720-X</td>
<td>PULSE Reflex Modal Analysis</td>
</tr>
<tr>
<td>Type 8721-X</td>
<td>PULSE Reflex Advanced Modal Analysis</td>
</tr>
<tr>
<td>Type 8722-X</td>
<td>PULSE Reflex Correlation Analysis</td>
</tr>
<tr>
<td>Type 8729-A-X</td>
<td>PULSE Reflex Spectral Analysis</td>
</tr>
<tr>
<td>Type 8729-B-X</td>
<td>PULSE Reflex Structural Measurements – Hammer and Shaker</td>
</tr>
<tr>
<td>Type 8729-C-X</td>
<td>PULSE Reflex Structural Measurements – Stepped Sine</td>
</tr>
</tbody>
</table>

* "X" indicates the license model, either N: Node-locked or F: Floating

Table 2 Overview of PULSE Reflex Modal Analysis packs (modal analysis packs and modal acquisition and analysis packs)

<table>
<thead>
<tr>
<th>Packs</th>
<th>8720-A</th>
<th>8720-B</th>
<th>8721-A</th>
<th>8721-B</th>
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<tbody>
<tr>
<td></td>
<td>Modal Analysis</td>
<td></td>
<td>Advanced Modal Analysis</td>
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<tr>
<td>Comprises:</td>
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<tr>
<td>PULSE Reflex Base Type 8700</td>
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<tr>
<td>Geometry Type 8719 (incl. animation)</td>
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<tr>
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<tr>
<td>Advanced Modal Analysis Type 8721</td>
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<tr>
<td>Modal Test Consultant Type 7753</td>
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<tr>
<td>MIMO Analysis Type 7764*</td>
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</tbody>
</table>

* Type 7764 is required for measuring MIMO FRFs in PULSE Modal Test Consultant Type 7753. Type 7764 is not required for polyreference curve-fitting in PULSE Reflex.

Table 3 Ordering information for PULSE Reflex Structural Dynamics suite’s maintenance and support agreements

<table>
<thead>
<tr>
<th>Item No.*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 8720-A-XS</td>
<td>PULSE Reflex Modal Analysis Pack</td>
</tr>
<tr>
<td>Type 8720-B-XS</td>
<td>PULSE Reflex Modal Acquisition and Analysis Pack</td>
</tr>
<tr>
<td>Type 8721-A-XS</td>
<td>PULSE Reflex Advanced Modal Analysis Pack</td>
</tr>
<tr>
<td>Type 8721-B-XS</td>
<td>PULSE Reflex Advanced Modal Acquisition and Analysis Pack</td>
</tr>
</tbody>
</table>

* "X" indicates the license model, either N: Node-locked or F: Floating