

Mass Property Measurements

Simple. Accurate. Reliable.



Mass

Center of Gravity (COG)

Moments of Inertia (MOIs)

Products of Inertia (POIs)

m

x, y, z

$I_{xx'}, I_{yy'}, I_{zz}$

$I_{xy'}, I_{xz'}, I_{yz}$

Mass Property Measurements

Essential for dynamic behavior

Ten mass property values characterize the movement of an object in three-dimensional space. Understanding these properties enables the prediction, optimization, and control of its dynamic behavior.

Resonic provides comprehensive products and services for accurate mass property measurements of objects of any shape, size and weight - from miniature fans weighing a few grams up to towering satellites weighing six tons (and more).



Resonic Measurement



Prediction and Control

Complete Mass Properties

Mass

Center of Gravity (COG)

Inertia Tensor

m

COG(x,y,z)

lxx sym.
lxy lyy
lxz lyz lzz



20g fan



2kg dummy head



200kg scooter



2t passenger car



2t ship model



6t satellite

Resonic Measurement Process

Full mass properties in less than 60 minutes

The interactive Resonic software guides the operator through a fail-safe measurement process. Full mass properties can be obtained in under 60 minutes, including fixture mass subtraction and transformation of results into the target reference system (test object preparation excluded).

Step 1

The test object is placed on a measurement platform, using fixture components if necessary. Precise alignment is not required.



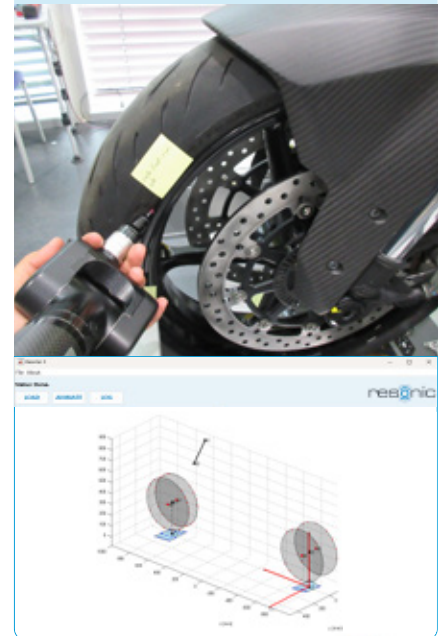
Step 2

The Resonic system measures the combined mass properties of the test object and fixtures.



Step 3

The object's precise location and orientation is obtained with a 3d measurement device. Using this data, the Resonic software transforms the mass properties into the test object's coordinate system.



Step 4

The test object is removed and the mass properties of the fixtures are measured. The Resonic software subtracts the fixture mass properties and produces a result report: test object mass properties in target coordinates.



Resonic F

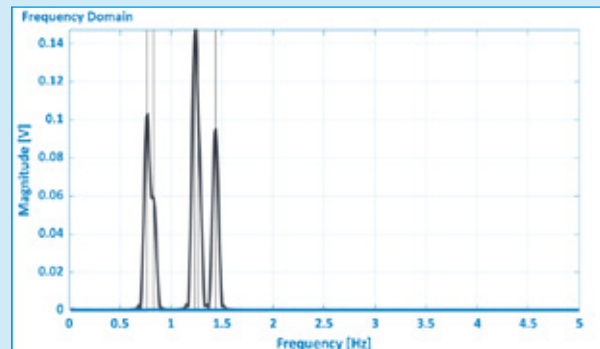
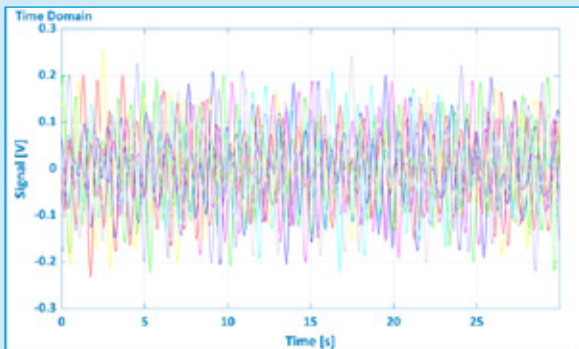
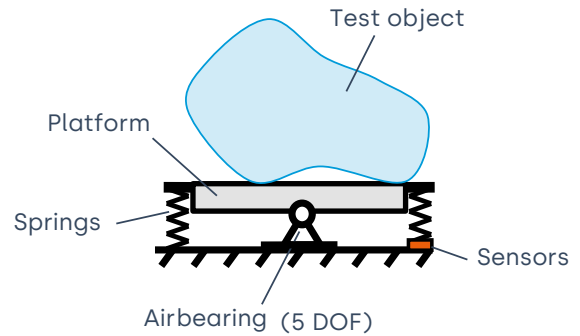
Technology for objects of any size and weight

Full mass properties are measured in a single, upright test object position, with minimal accelerations ($< 0.1 \text{ m/s}^2$) and amplitudes ($< 2 \text{ mm}$).

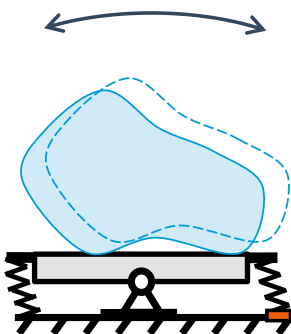
The measurement platform is supported by a frictionless air bearing with five degrees of freedom (DOF) and soft springs.

Following an initial imprecise push, the platform oscillates freely, exhibiting five simultaneous vibration modes.

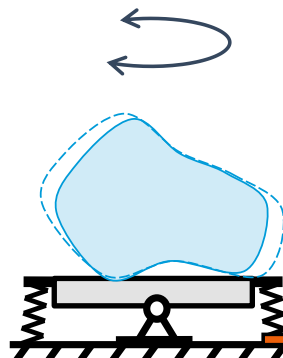
The Resonic software captures the vibration signals and derives the full mass properties.



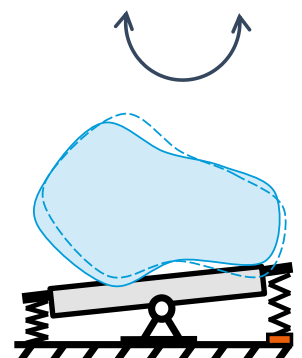
Mode 1/2



Mode 3



Mode 4/5

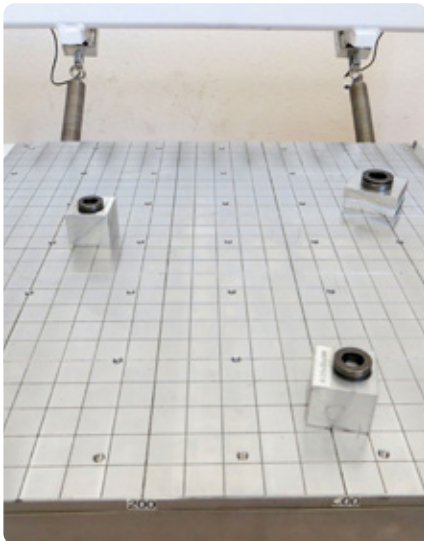


Resonic F

Technology for objects of any size and weight

Unique benefits include:

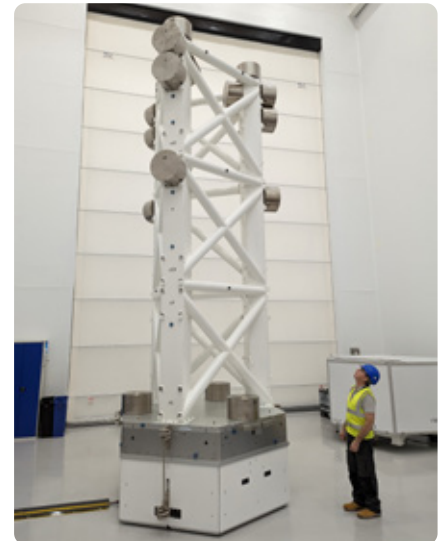
- Minimal fixtures and outstanding safety thanks to low accelerations and a horizontal platform.
- Compact, mobile devices with low mechanical complexity. Installation in under an hour and without special facility requirements.
- High accuracy facilitated by the frictionless air bearing and special calibration methods. Equipment for accuracy checks is included.
- Unlimited workspace. The test object can be much larger than the platform, allowing the device to cover an exceptionally wide range of objects.
- Simple operation. Can be learned in a few hours. The software detects rare human errors by displaying various quality indicators.



Typical fixture: three contact points and no clamping

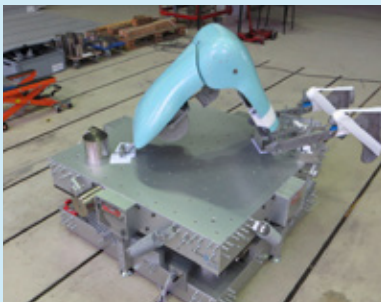


Set up after transport (Resonic 500F)

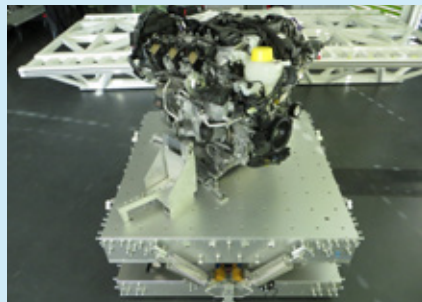


System with precisely known mass properties used for accuracy checks (Resonic 6000F)

One and the same Resonic system can handle an enormous range in terms of size and weight:



Dummy driver



Engine



Van (using a vehicle adapter)

Resonic K and P

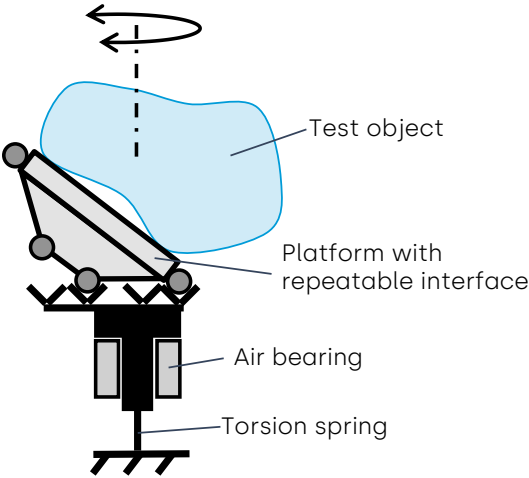
Technology for small objects

Resonic devices for small test objects use a frictionless air bearing pendulum.

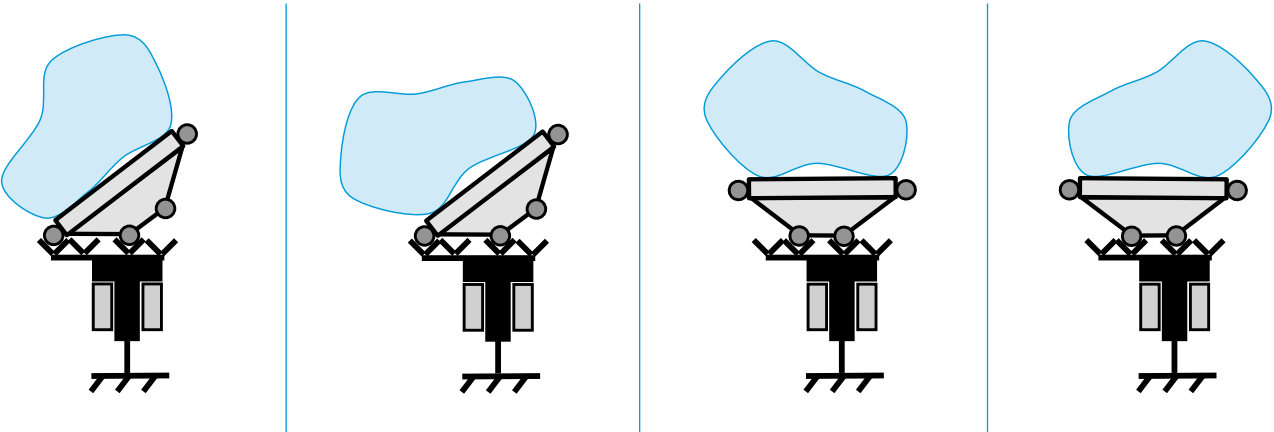
The measurement platform features an interface which enables repeatable placements in discrete positions on the pendulum.

Each platform position has a different orientation and/or different offset from the pendulum axis.

The operator positions the platform as directed by the software. The software then measures the oscillation frequency.



Examples of different platform positions:



Resonic K and P

Technology for small objects

Resonic K and P provide the same benefits as for Resonic F in terms of simplicity, accuracy and workspace. However, for small objects, they

present a more economical solution. Due to measurements in tilted platform positions, sturdier fixtures are required.



Up to 20 kg: Resonic K. The platform is moved by hand.



Up to 80 kg: Resonic P. The platform is moved by spindles.



After measuring all 24 positions (in the standard mode), the process is repeated for the empty fixture before the software computes the full mass properties.



One pendulum can be paired with multiple platform sizes to maximize the range of possible test objects.

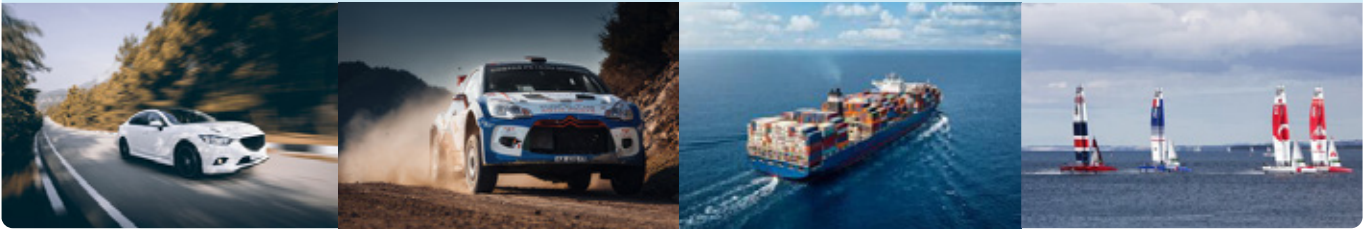
Applications

For various engineering goals

Accurate, reliable, and efficient measurements of mass properties are required across various industries. The following examples illustrate typical application areas.

Movement Analysis

Mass properties are essential for predicting, analyzing and optimizing the dynamic behavior of moving objects – whether driving, flying, or floating.



Control Systems

Mass properties play an important role in designing reliable control systems to ensure stability, performance, and safe maneuvering.



Vibration Control

Knowing the mass properties is important for vibrating objects to design effective mounting and damping systems.



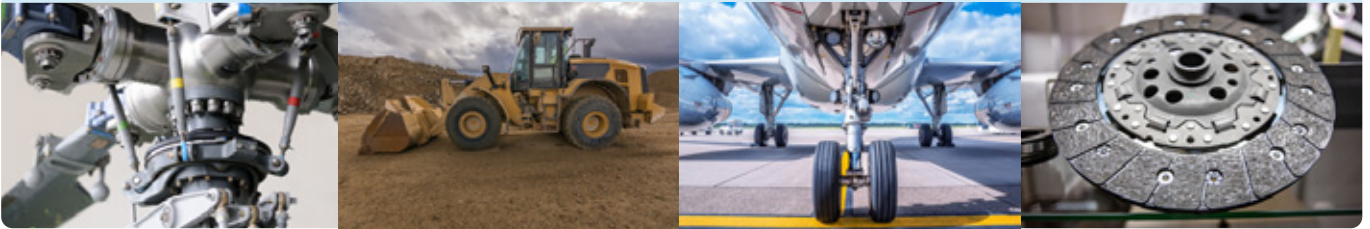
Applications

For various engineering goals

Besides these typical application areas, mass property measurements are used in various special projects. For example, high-precision Resonic T measurements have been used in battery cell research to investigate electrolyte behavior as a function of charge state.

CAE Simulation

Mass properties are frequently utilized in simulations and modeling to accurately characterize the behavior of objects in various environments and conditions.



Product Development / Reverse Engineering

Comparing mass properties with competitors' products and industry standards can provide insights to enhance performance, efficiency, and safety of products.



Safety and Compliance

Various standards prescribe tolerances for mass properties and explicitly require measurements to ensure compliance.

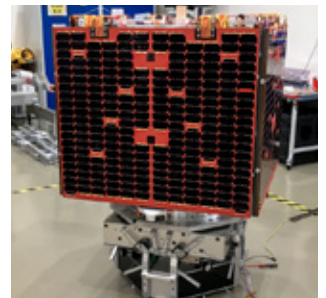
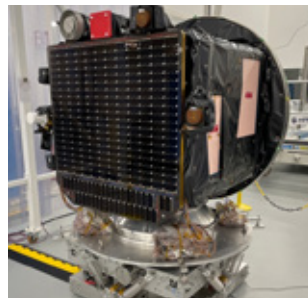
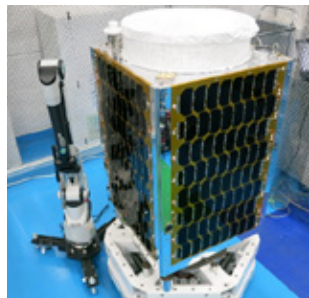
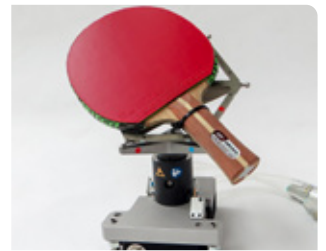
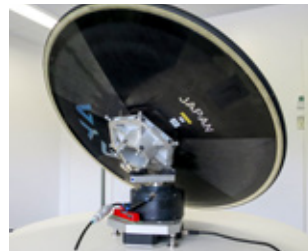
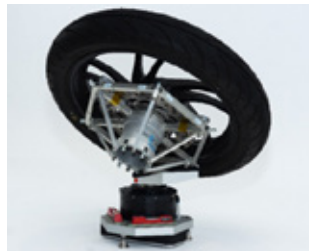


Applications

For a wide range of test objects

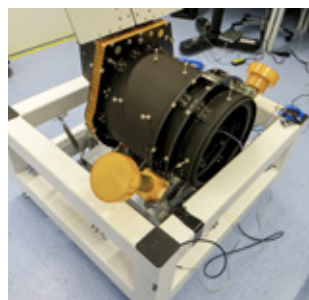
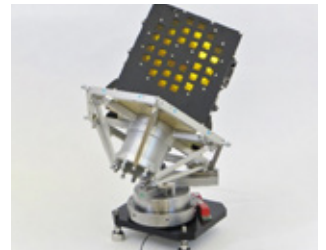
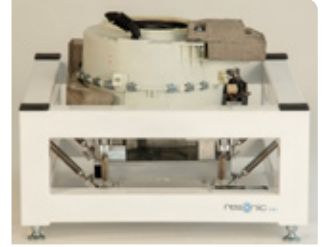
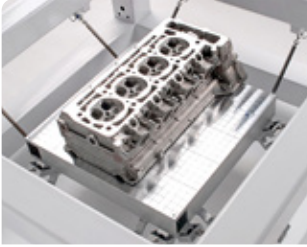
Resonic systems are utilized across industries for measuring a wide variety of objects. Whether moving components and rotating parts, helmets

and crash dummies, sporting goods, all kind of vehicles, or flying and floating objects, Resonic's solutions cater to diverse measurement needs.



Applications

For a wide range of test objects

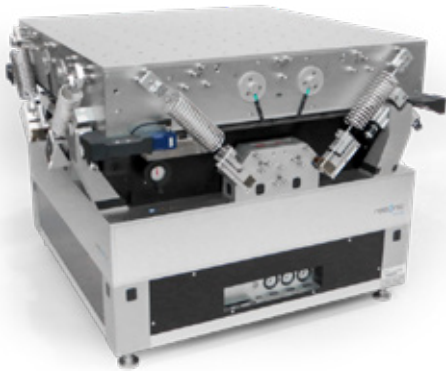


Product Lines

Resonic F and S

resonic

F



Resonic F

Test objects from 10kg to 9,000kg with COG heights up to 4m (current limits).

Standard sizes⁽¹⁾: 150F, 500F, 1500F, 3500F, 9000F

Accuracy for full mass properties⁽²⁾:

- Izz: 0.4% | Ixx, Iyy: 1% | Ixy, Ixz, Iyz: 1% of largest MOI
- Horizontal COG: 0.2mm + 0.005% of COG height
- Vertical COG: 1mm up to 650mm COG height, otherwise 0.15% of COG height

resonic

S



Resonic S

Low-cost version of Resonic F with limitations: lower accuracy, installation space limited by a support structure, suitable only for rigid test objects such as wheels, combustion engines, and gear units. Available for objects between 20kg and 700kg.

Standard sizes⁽¹⁾: 100S, 350S, 700S

Accuracy for full mass properties⁽²⁾:

- Ixx, Iyy, Izz: 3% | Ixy, Ixz, Iyz: 3% of largest MOI
- COG: 3mm for 100S, 4mm for 350S, 5mm for 700S

⁽¹⁾ The product number corresponds to the maximum test object weight in kg.
⁽²⁾ Detailed test data available upon request.

Product Lines

Resonic K/P and T

resonic

K



resonic

P



resonic

T



Resonic K/P

Test objects from 20g to 20kg for Resonic K. Test objects from 3.5kg up to 80kg for Resonic P.

Standard sizes⁽¹⁾: 2K, 10K, 20K, 80P

Accuracy for full mass properties⁽²⁾:

- I_{xx} , I_{yy} , I_{zz} : 0.7% | I_{xy} , I_{xz} , I_{yz} : 0.7% of largest MOI
- COG: 0.2mm up to 200mm COG height, otherwise 0.1% of COG height

Resonic T

Measures only a single moment of inertia (around the pendulum axis) instead of full mass properties. Typical applications include rotors, shafts, clutches, wheels, propellers – mainly objects that rotate about a fixed axis.

Resonic T uses the same air bearing pendulums as Resonic K and P, but is combined with a fixed, horizontal platform.

Standard sizes⁽¹⁾: 10T, 30T, 60T, 100T

Accuracy for moment of inertia⁽²⁾:

- I_{zz} : 0.1%

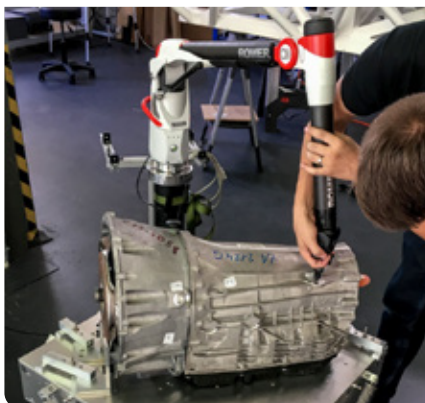
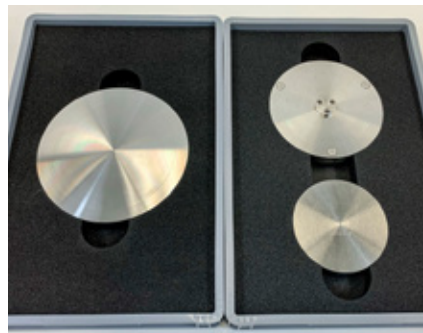
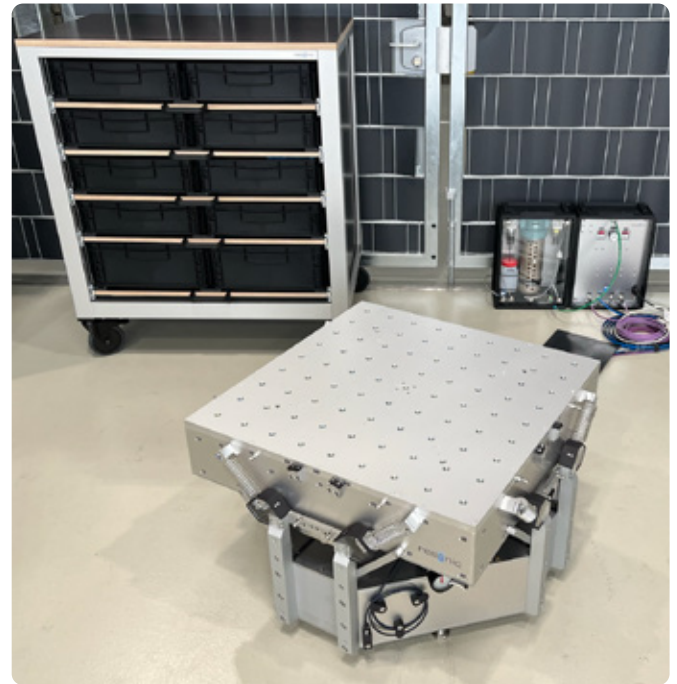
⁽¹⁾ The product number corresponds to the maximum test object weight in kg.
⁽²⁾ Detailed test data available upon request.

Focusing on the Entire Process

Tools, equipment and helpful features

Resonic systems cover the complete measurement workflow and include:

- Tools and equipment for handling, transporting, and storing the Resonic device.
- All necessary accessories, including air preparation units, cables, and hand tools, complete with storage solutions.
- Coordinate transformation software compatible with most common 3d measurement systems.
- Equipment for calibrations and accuracy checks.
- Optional tools and equipment for lifting and interfacing test objects.



Measurements as a Service

Alternative to owning a measurement system



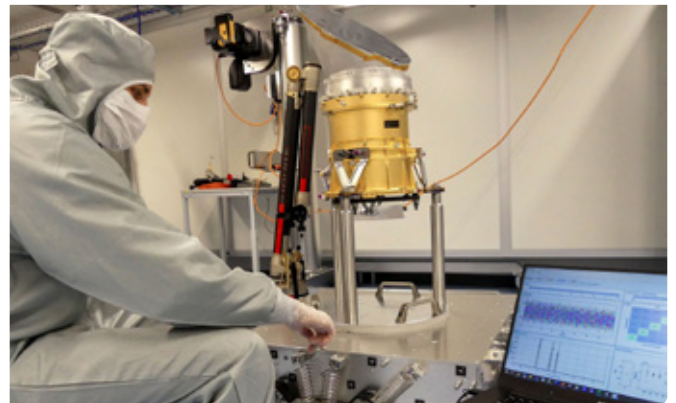
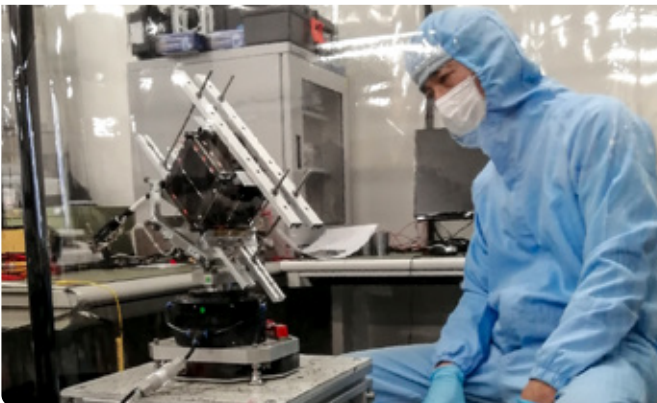
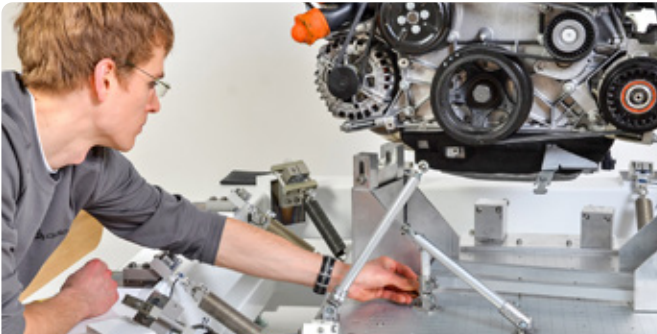
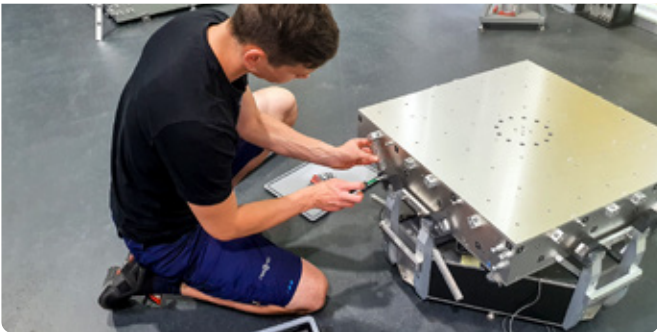
In addition to turn-key measurement systems, Resonic offers measurements as a service for almost any kind of test object.

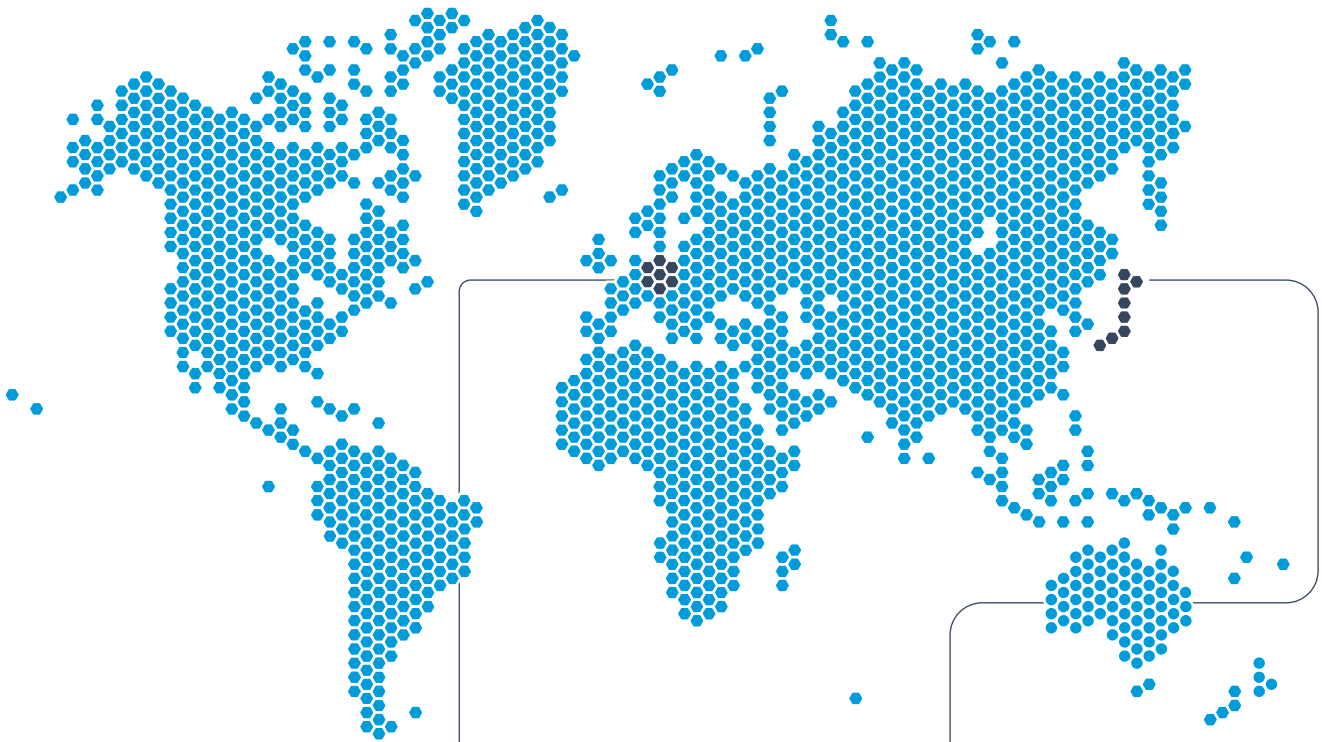
Whether on-site or at our facilities, Resonic can provide all the equipment needed for the measurements, including:

- Mass property measurement device
- Lifting tools
- 3d measurement system
- Fixtures/adapters

A Resonic engineer sets up the equipment and performs the measurements.

Even time-critical test campaigns (e.g., Formula1) or specialized environments (e.g., clean rooms) are not a problem.





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