



How Motion Amplification[®] Fits into Your R&D, Test, Quality, and Reliability Programs

For Aerospace, Defense, and
Space Organizations

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CAPTURE, VIEW, AND ANALYZE DATA IN JUST MINUTES VERSUS HOURS AND DAYS WITH SENSORS

Designing and manufacturing advanced aerospace products for commercial, defense and space applications requires bringing these products to market safely and cost-effectively while meeting stringent testing, certification, and quality demands. From design to quality, reliability and performance, every stage of the development process requires specified mechanical and material testing to ensure safety and durability requirements.

Leading commercial and military aerospace organizations were among the first to adopt RDI's **Motion Amplification**® technology several years ago, and they continue to play a significant part in advancing features, innovations, and add-ons, as valued customer partners. Today, RDI Technologies® is a respected global leader in **Motion Amplification** in the aerospace, defense, and space industries.



IRIS M™ with Motion Amplification

FIRST, WHAT IS MOTION AMPLIFICATION?

Motion Amplification is a patented camera-based technology developed by RDI Technologies that allows users to see - in real time - motion that is invisible to the human eye or can be difficult to measure with traditional sensors.

Motion Amplification technology turns every pixel in the camera's view into a sensor capable of measuring vibration or motion with unparalleled levels of accuracy. It can resolve motions as small as <math><0.01</math> mils (0.25 Microns) at 1 meter and can be performed live and in real-time on even a modest laptop, making it suitable for a range of applications from product design and testing to field-based machinery fault diagnosis and structural testing.

By amplifying and visualizing these small movements, **Motion Amplification** can provide aerospace engineers with insights into the health and performance of new and existing products including identifying potential issues before they become critical problems.



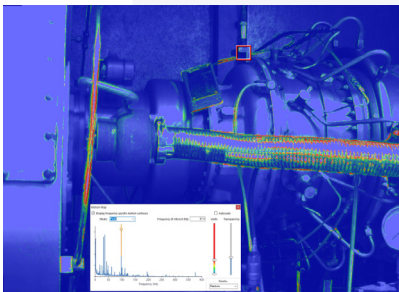
HOW MOTION AMPLIFICATION® WORKS

Motion Amplification works by using high definition and high dynamic range video cameras where every pixel becomes an independent point sensor creating millions of continuous data points in an instant. This essentially turns a high-definition camera into a full-field vibration acquisition device with over 2.3 million independent sampling locations. This makes it a great troubleshooting tool, a quick and effective alternative to traditional ODS, an effective decision making and communication tool between technical and non-technical personnel.

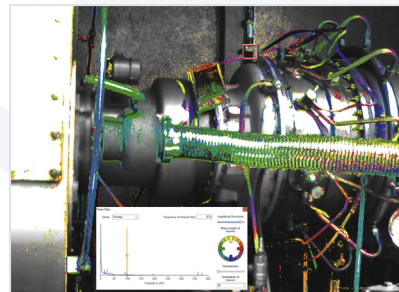
With **Motion Amplification** software you can quickly analyze and understand the vibration frequencies, amplitudes, and waveforms in the scene.

Motion Amplification videos can be immediately analyzed by applying Frequency Filtering, Motion and Phase Color Maps, and Vectors. The Frequency-based Filtering feature enables filtering the video data sets to show motion only at a particular frequency. Motion and Phase Color Maps allow for a rapid way to analyze the motion and relative phase in a field to quickly understand the dynamics and motions present along with relationships of motion. Vector overlays are a useful way in which to visualize complex motion across a full-field of view.

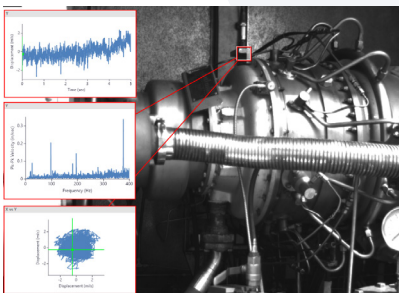
Motion Amplification visualization provides a unique communication channel when reviewing and sharing test results with technical and non-technical personnel.



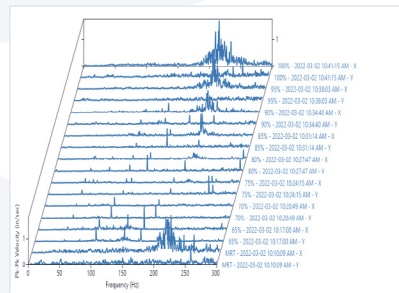
Motion Map Motion Map in RDI software uses color to draw attention to where motion is present.



Phase Map in RDI software uses color to convey the phase relationship between the different components of an asset.



Annotation feature in RDI software enables you to plot and incorporate vibration data into **Motion Amplification** videos.



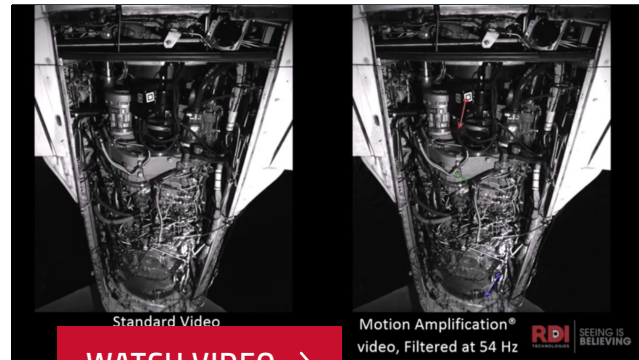
Historical Data Analysis enables you to compare data from different data sets.

100% COVERAGE OF TEST ARTICLE & TEST RIG

RDI's **Motion Amplification**® is used for a wide range of non-contact and non-destructive measurement applications in research, product, and quality assurance testing. There is no painting, gluing, or surface modification required, which makes Motion Amplification a good fit for modal and reliability testing.

The technology produces full-field data vs. single point measurements, provides 100% coverage, allowing you to test the entire test article, including a test rig.

Videos and data are produced within seconds of data collection, saving you time and money while accelerating your time to market.



Jet engine non-contact vibration measurement.



VISUALIZE

Detect subtle displacement (as small as 0.25 Microns) with RDI's propriety video processing software; converts movement to a level visible to the naked eye.



MEASURE

Measure and quantify mechanical or structural assets that a camera can see with the same accuracy as a industry-standard accelerometer.



COMMUNICATE

Enhance your understanding through helpful videos and provide a communication tool between technical and nontechnical resources.



TROUBLESHOOT

Filter data and visualize motion at specific or overall frequencies to find the real source of a problem and position your team to fix it.



MOTION AMPLIFICATION®

IN AEROSPACE



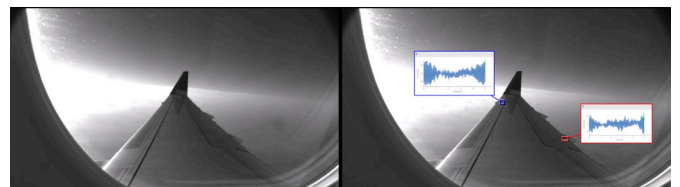
EASE OF USE. POINT-AND-CLICK WITHOUT TOUCHING THE STRUCTURE.

- Millions of pixels are converted to non-contact virtual sensors that measure vibration amplitude and frequencies.
- Camera setup, recording measurements/videos and data processing usually take less than 10 minutes.
- Full-Field vibration testing (100% asset coverage)
- Visualize the entire asset in one collection
- Every point is measured and quantified. No guessing between points



GROUND VIBRATION TESTING (GVT)

Visualize and troubleshoot entire aircraft, helicopter or space vehicle including airframe, landing gear, engines, and rotors to ensure that components are working as designed.



DYNAMICS AND STRUCTURAL ANALYSIS

Drill down to regions of interest (ROIs) for a detailed look at vibration frequency, amplitude, phase, orbit plots, and time waveforms.

TEST FIXTURES & TEST CELLS

Vibration test cells for components, engines and power transmission equipment are typically instrumented with many single point contact sensors to capture data. In most test rig applications, sensors are cost and labor intensive, and it's challenging to have one hundred percent sensor coverage. As a non-contact and camera-based solution, **Motion Amplification**® reduces set-up time and labor while allowing users to acquire millions of simultaneous vibration measurements in one platform.

If the test requires the use of contact sensors, **Motion Amplification** adds value by quickly helping to see what is moving where to figure out optimum placements of strain gauges and sensors. This will save time and reduce costs by knowing the node locations and or eliminating some strain gauge and sensor placements.

IRIS CM™ - CONTINUOUS MONITORING IN TEST CELLS

Considering that many test cells are performing long duration vibration tests under various environmental and operating conditions, with the **Iris CM™**, you can continuously monitor your test cells while you are away. This tool connects traditional vibration inputs and RDI's patented video-based vibration measurements to ensure you never miss anything in your test labs. Numerous cameras can be networked to capture simultaneous data and offer multiple views of a process, test, or piece of machinery.

As a powerful acquisition device, the Iris CM can acquire and store HD data for each connected camera along with external sensor data from accelerometers, tachometers, and any 4-20 mA input. Users can trigger video and data recordings based on external inputs, virtual camera-based regions of interest, and thresholds for movement.

With Iris CM test lab engineers can quantify vibration, amplitude, phase, and frequency for anything visible in the recorded video. Iris CM uniquely allows you to perform live **Motion Amplification**, troubleshoot transient events and visualize your test article over longer periods of time like no tool has before. The Iris CM does not have to be permanently mounted and does not have to touch any of your equipment. With the Iris CM, you now have the ability to see what is happening on your equipment 24/7 even when you are away.

TEST RIG PERFORMANCE

Motion Amplification has been used to pre-screen 100% of test fixtures and cells for imbalances, mechanical looseness, misalignments, and other vibration problems that can impact the overall performance and reliability. Operating a test cell with minimal vibrations also helps to improve the data quality of test articles.

ENGINE AND SUB-COMPONENT TEST

Motion Amplification is used to measure and visualize vibrations on full or partial engines, sub-components and rigs in test cells or on shaker tables.



ROTATING EQUIPMENT INSPECTION

Rotating components such as couplings, rotors and blades can be challenging to measure because the vibrations and motions of interest often present themselves only when the components are undergoing rotation.

Measuring vibration is somewhat limiting, proximity probes can be used for a point measurement of a rotating shaft, but they are cumbersome and limited to ferrous material and only measure one point. Likewise, laser vibrometers can measure point locations but are limited in use as well. Finally, contact sensors such as strain gauges require affixing to the shaft securely and wireless data transmission to retrieve the information.

Several techniques are available with **Motion Amplification®** and leveraging the camera for full field measurements. They are broken into two techniques, **Rotating Components Inspection** and **Synchronously Triggered Motion Amplification** and **Subsequent Measurement**.

ROTATING COMPONENTS INSPECTION

The camera can be put in a special mode that accounts for the turning speed of the rotating components and images in the scene at a rate that allows the rotating component to be visible and non-blurred despite the rate of rotation being much faster than the camera frame rate. This allows for a visual inspection of a shaft, coupling, rotor or blade. This can be advantageous when the machine cannot be stopped at a convenient time, or the inspection needs to be done during operation as the element that could indicate a fault only does so during operation.



SYNCHRONOUSLY TRIGGERED MOTION AMPLIFICATION AND SUBSEQUENT MEASUREMENT

Another technique involving rotating components and blades is synchronous triggering acquisition. This technique allows for the camera frame rate to be synchronized with an external signal such as a laser tachometer that pulses each revolution at the same rotational position. The result is the acquisition being acquired at synchronous speeds effectively freezing the rotating element.

Motion Amplification® can then be applied along with time waveform and spectral measurements to image and visualize nonsynchronous motion such as mode shapes or torsional motion.

ROTOR BLADE TESTING

Changes in rotor blade concepts, design and materials make the need for testing more critical. Iris M™ Tach Sync offers a unique method to freeze synchronous motion of a shaft or blade, the remaining motion can then be amplified.

3-DIMENSIONAL & MODAL TESTING

Simplify the process from capture, to analyze, to action for faster time to market.

MOTION AMPLIFICATION AND STEREO VISION

Iris M + Stereo Vision™ is a two-camera **Motion Amplification®** system that will enable full-field vibrational measurements to be taken simultaneously in all directions (3 dimensions/ axes). Iris M + Stereo Vision uniquely gives users the ability to acquire synchronized waveform and spectral data in 3 dimensions for virtually any region of interest, anywhere on the asset, in just one data capture.

This multidimensional measurement is engineered to function as one system, helping to avoid over- or under-testing problems caused by single-axis vibration tests. Iris M + Stereo Vision increases visibility, and efficiency and helps users see patterns, trends, and non-obvious relationships in just a single test.

VIBRATION SHAKER TESTING

Vibration shaker testing are critical for ensuring the safety and reliability of aerospace components and vehicles during operation. **Motion Amplification Stereo Vision** allows for set-up of single or two calibrated Stereo Vision cameras (3-dimensional measurements) to measure frequency, amplitude, and direction of the vibration. For longer duration vibration tests, a **Motion Amplification Continuous Monitoring** solutions can continuously monitor and perform triggered acquisitions of vibration testing while you are away.

IMPACT TESTING /MODAL ANALYSIS

With **Modal Amplified**, our Modal Test and Analysis solution, you can leverage simultaneous measurement of the force input with the response measured directly from the camera. This allows you to use the camera and impact hammers to quickly acquire data to detect bending modes, natural frequencies and resonances.

Users can immediately visualize the resulting modes shapes, and they can place an unlimited number of modes across the structure through virtual regions of interests. Virtual sensor measurements include waveform, spectrum, coherence maps, FRF, phase, and force input. Stability plots also show where mode shapes are stable in frequency and damping.

This approach allows users to have modal results in a matter of minutes, from capture to visualizing the modes shapes, complete with dozens, even hundreds of sensors measured across the structure.

DESIGN VALIDATIONS, MODELING AND SIMULATION

Use **Motion Amplification** videos to validate computer modeling of new and existing components in test rigs that simulate complete units.





CASE STUDIES

TINKER AIR FORCE BASE

OKLAHOMA

The United States Air Force has already employed RDI's video **Motion Amplification**® technology to carry out and assess predictive maintenance for equipment. The 76th Maintenance Support Group's Industrial Engineering shop at the Oklahoma City Air Logistics Complex uses a **Motion Amplification** camera and accompanying software to maintain and inspect equipment.

The Airforce unit even used RDI's motion enhancement technology to inspect and evaluate faulty vacuum pumps and water pumps, finding that loose mounting bolts and a cracked concrete base were causing issues. Such action enabled cost-saving preventive maintenance.

Technicians can further use **Motion Amplification** vibration analysis during jet engine testing and to evaluate aircraft wings' flex performance. And since jet engines are not small machines, using a contactless vibration analysis method increases safety and permits analysis without touching or interfering with machinery's operation.

COMMISSIONING NEW ASSETS

Engineering Technicians noticed a defect in a new water pump. Their early detection allowed the Complex to immediately identify errors for the contractor to resolve rather than using government dollars to fix the problem later.

This find had a calculated cost avoidance of \$176,000.

TROUBLESHOOTING

OC-ALC engineering technicians say the equipment has paid for itself very quickly. Vibration engineering technician Jeff Gazaway recalls walking by a vacuum pump on a regular inspection route and noticing a pipe moving more than he thought it should. "We assumed it was a loose bolt" said Gazaway. However, he said, the team utilized the camera for a closer inspection and found a total displacement of 28mils or .028 – enough to eventually cause catastrophic failure.

"If a picture is worth a thousand words, a slow-motion video is worth about 2.3 million," said engineering technicians Jason Stroup and Tyler Walker.

"You can talk all day long to an engineer about movement, but they're awestruck when they see it," said Stroup. "This is the most exciting tech we've had in the last ten years."

ARNOLD AIR FORCE BASE

TENNESSEE

As part of the Condition-Based Monitoring vibration program at Arnold Air Force Base in Tennessee, readings are taken regularly from equipment in the Arnold Engineering Development Complex facilities. The team uses RDI's Iris M™ **Motion Amplification**® camera to assist in identifying causes and recommending corrective actions for excessive vibrations at several locations around Arnold AFB, from expected components, such as motors and compressors, to atypical situations, such as piping. Vibration sensors enable the team to define the motion numerically, while the high-speed camera generates an amplified motion video allowing them to see the motion.

ROOT CAUSE ANALYSIS AND PROBLEM SOLVING

At the AEDC Propulsion Wind Tunnel Facility, vibration levels reached problematic levels in the east and west blowers. The proposed solution was to rebalance the fans only. Using the camera, the team determined the problem was lack of stiffness at the base plate of the motor.

UNUSUAL VIBRATIONS FROM PIPING

An unusual source of a vibration was identified with the camera in a cooler at the Engine Test Facility. The entire system was shaking. Using the camera, the team identified the major source of the vibrations appeared to be from fluid hammering within the piping.

“We’ve found one of the most useful features of the Motion Amplification Camera is that it can visualize the motion of a machine, simplifying the explanation of a typical vibration problem,” Matthew Breuhl, the AEDC CBM Vibration Lead.

“We are able to show the video to team members needing to understand how the machine is actually moving.”

MOTION AMPLIFICATION[®] SOLUTION SUITE



Iris M™
Video-based Sensors



IRIS CM™
Continuous Monitoring



Iris MX™
Extended Frequency



Modal Amplified
Modal Test & Analysis



Iris M + Spot™
Robotics



Stereo Vision
Simultaneous,
3-dimensions/axes



External Laser
Tachometer



Iris M Traveler™
Rugged On-the-Go

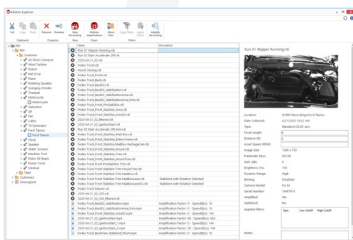


Color Camera
Iris M™ Add-on



Fastec™
High-speed
Cameras

MOTION AMPLIFICATION SOFTWARE SUITE



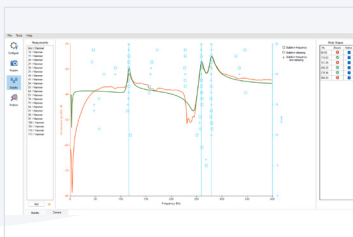
MOTION EXPLORER
Database set-up and file management



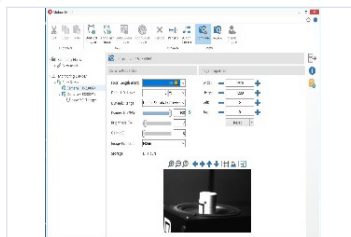
ACQUISITION
Camera configuration, live MA, initiate
new recordings



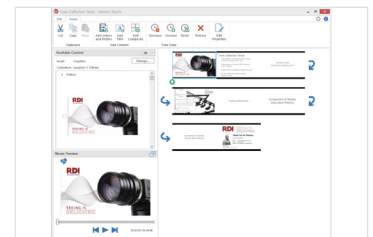
MOTION AMPLIFICATION
Motion Amplification tools for analysis
of recordings



MODAL AMPLIFIED
Modal test and analysis with impact
hammers and shakers



MOTION MONITOR
Iris CM set up and configuration for
continuous monitoring



MOTION STUDIO
Easy to use video editor to enhance
communications and reporting

RDI TECHNOLOGIES®

HERE TO SERVE YOU

RDI offers a wide range of support and services necessary to meet the needs of every customer – from daily operation, routine and scheduled maintenance to outage services and R&D/Service Modal Testing. We're to help you inspect more assets in less time, reduce risk, improve workflow, and stay focused on your critical assets and core business.

- Certified **Motion Amplification®** Training (Basic, Advanced, Remote)
- Consulting - POC, **Motion Amplification** Implementation
- Machinery Performance, Diagnostics, and Troubleshooting
- **Motion Amplification** Facility Audit/Assessment
- Modal Testing and Analysis Services
- Software/Hardware Upgrade and Support (Software/hardware updates, Continuous Training)
- Responsive Support (Technical and domain expertise on-demand; remote and in-field)

How can we help?

For a more detailed look at our service offerings visit www.rдитеchnologies.com/services/

Or email us at services@rdитеchnologies.com



SEE MOTION AS IT REALLY IS...

Seeing is Believing®

ABOUT RDI TECHNOLOGIES®

As a leading global vibration technology and visualization solutions innovator, RDI Technologies enables reliability and test and measure programs to make faster, safer, and more informed decisions through intelligent vibration equipment, data analytics, robotics, and services, driven by its proprietary **Motion Amplification®** measurement platform. With 200 years of reliability and test and measurement industry experience, RDI Technologies helps clients in more than 60 countries and 40 industries gain greater speed to insight while reducing risk and cost. Over 700 corporate and government global customers including Google, Nissan, Duke Energy, Newmont, Amazon, Chevron, and US Navy rely on RDI's breakthrough **Motion Amplification** platform to see and measure motion previously impossible to visualize by contacting sensors.

Follow us on **LinkedIn**, **Twitter**, **Instagram**, and **YouTube** for the latest news, or visit our website **www.rditechnologies.com** for more information.

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