

## WHITE PAPER

# From Invisible Defects to Measurable Quality

*How Magnetic Field Mappers and Magnetic Field Cameras Accelerate Development, Improve Manufacturing Quality, and Deliver Fast ROI*

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## EXECUTIVE SUMMARY

As electric vehicles, robotics, industrial automation, and smart sensing systems become increasingly dependent on magnetic components, manufacturers face a growing challenge: critical magnetic defects often remain invisible until they appear as performance problems, production losses, or customer complaints.

Traditional quality control methods focus on dimensions, materials, and electrical performance. However, they rarely measure the magnetic field itself — the physical quantity that ultimately determines the functionality of motors, encoders, magnetic sensors and systems.

**SENIS' Magnetic Field Mappers and Magnetic Field Cameras** provide a direct view into magnetic behavior, enabling developers and manufacturers to detect defects earlier, validate simulations more accurately, accelerate product development, and improve production yields.

This paper explains how these technologies work, where they create value, and why leading manufacturers increasingly integrate magnetic measurement into their design and manufacturing workflows.

## THE MAGNETIC VISIBILITY PROBLEM

Most manufacturers inspect what they can easily see:

- Dimensions
- Surface quality
- Material composition
- Electrical performance

However, magnetic systems often fail because of characteristics that cannot be visually inspected, such as:

- Incorrect magnetization
- Weak magnetic poles
- Pole position errors
- Assembly misalignment
- Partial demagnetization
- Magnetic field distortion

These issues may only become apparent after assembly, during end-of-line testing, or even after products reach customers. **As a result, engineering teams spend significant resources troubleshooting symptoms rather than identifying root causes.**

## MAGNETIC FIELD MAPPER: PRECISION MAGNETIC METROLOGY

A Magnetic Field Mapper measures the magnetic field at thousands of locations and generates a detailed three-dimensional representation of the magnetic field distribution.

The system typically measures  $B_x$ ,  $B_y$ , and  $B_z$  field components, total magnetic flux density, pole positions and variations, angle and offset errors, harmonic content, and field homogeneity. The resulting dataset creates a digital magnetic fingerprint of the component.

### Key Advantages of SENIS Magnetic Field Mappers

1. **Measure the full 3D magnetic field at once.** Unlike many systems that require multiple measurements or probe orientations, SENIS mappers measure  $B_x$ ,  $B_y$ , and  $B_z$  simultaneously at essentially the same point using 3-axis Hall probes. This gives the most accurate representation of the actual magnetic field.
2. **Very high accuracy and repeatability.** Mappers offer measurement accuracy around 0.1% and positioning repeatability down to a few micrometers, which is valuable when validating designs, comparing prototypes, or performing quality control.
3. **Excellent for electric motors and rotor analysis.** The mapper creates detailed field maps, measures pole positions, evaluates magnetic angle errors, and identifies performance issues before assembly. Suitable for sensor magnets, encoders, robotic actuators, and all kinds of motors.
4. **Powerful visualization and analysis software.** Generates 3D field maps, measures pole width, counts poles, detects zero crossings, analyzes field homogeneity, calculates magnetic angle errors, performs pass/fail evaluations, and detects cracks in magnets and magnetic assemblies.
5. **Traceable measurements.** SENIS calibrates its probes in its ISO/IEC 17025 accredited laboratory, which is important if measurements must be defensible in R&D, certification, or production environments.
6. **Useful in both R&D and manufacturing.** Used for magnet characterization, motor development, production quality control, failure analysis, simulation validation, and research laboratories.
7. **Easy transfer from development to routine operation.** Once the measurement procedure has been established and validated, the mapping process can be executed reliably **by technicians** and operational staff without requiring deep magnetic measurement expertise. This helps standardize testing, reduce dependence on specialized engineers, and ensure consistent results in production and quality-control environments.

## MAGNETIC FIELD CAMERA: REAL-TIME MAGNETIC VISUALIZATION

While a mapper provides maximum measurement precision, a Magnetic Field Camera focuses on speed and visualization. Instead of scanning point by point, the camera displays the magnetic field distribution instantly.

The technology functions similarly to thermal cameras for temperature, or X-ray systems for internal structures — except it visualizes magnetic fields.

## Why Real-Time Magnetic Imaging Matters

Engineers often ask: which magnet is defective? Why is the motor vibrating? Why is the encoder unstable? Why does the sensor output differ from simulation? Without magnetic imaging, these questions may require days or weeks of investigation. With a magnetic field camera, engineers can often identify the problem within minutes.

## Production Troubleshooting

A magnetic field camera enables rapid identification of missing poles, magnetization defects, assembly errors, magnet shifts, cracked magnets, and process drift. This dramatically reduces troubleshooting time and increases production uptime.

## Research and Development Benefits

Real-time magnetic imaging enables engineers to observe field changes instantly, evaluate design modifications rapidly, compare prototypes visually, and demonstrate magnetic behavior to customers. The result is faster innovation and shorter development cycles.

### MAPPER VS. CAMERA: CHOOSING THE RIGHT TOOL

A mapper tells you: *“What is the magnetic field distribution of this part?”*

A camera tells you: *“What is happening right now, instantly, across the entire area?”*

The value proposition shifts from precision metrology to speed, visualization, and real-time diagnostics. Many advanced manufacturers deploy both technologies because they solve different problems.

Magnetic Field Mapper	Magnetic Field Camera
<b>Best for:</b>	<b>Best for:</b>
Precision measurement	Troubleshooting
Simulation validation	Production diagnostics
Product qualification	Process monitoring
Metrology	Real-time visualization
Quality assurance	Demonstrations
<b>Primary value:</b> Quantitative accuracy	<b>Primary value:</b> Speed and insight

### APPLICATION 1: ELECTROMAGNETIC SIMULATION VALIDATION

Electromagnetic simulations are essential in modern product development. Engineers use software such as ANSYS Maxwell, COMSOL Multiphysics, or Altair Flux to predict air-gap fields, motor torque, sensor signals, encoder accuracy, and magnetic forces.

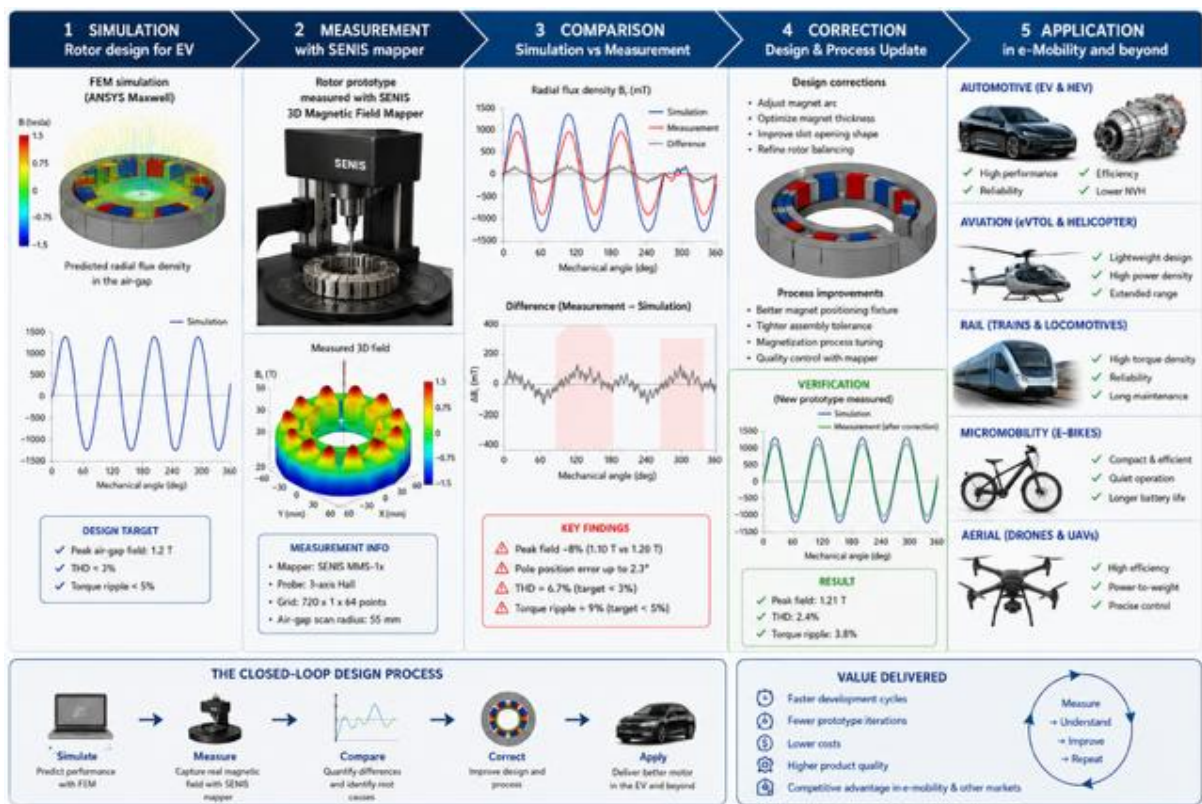
However, simulations assume perfect material properties, ideal geometries, exact magnetization, and zero manufacturing variation. Real products rarely match these assumptions. After manufacturing a prototype and mapping the magnetic field, developers

might detect lower remanence, assembly errors introducing harmonics, or inadequate magnetization processes.

### Closed-Loop Design Process

- Simulate motor or magnetic assembly
- Manufacture prototype
- Measure magnetic field using mapper
- Compare simulation with reality
- Correct simulation model
- Optimize design
- Release validated product

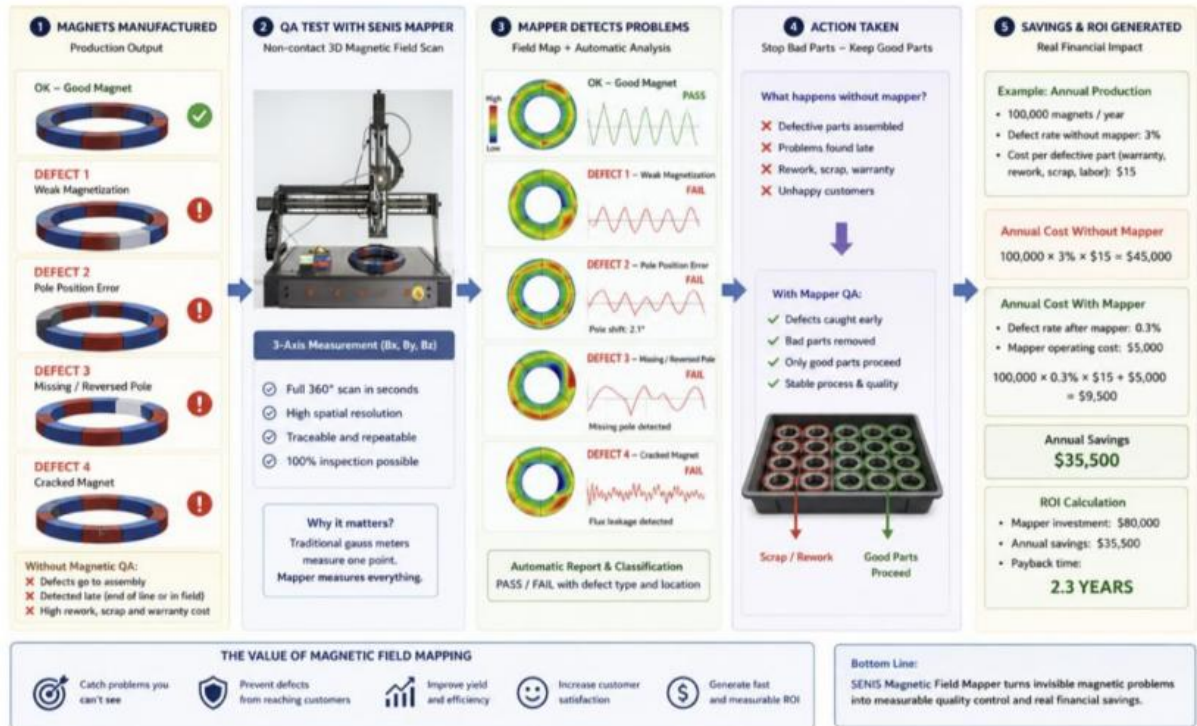
This process significantly reduces engineering uncertainty and lowers the number of prototype iterations required.



## APPLICATION 2: MOTOR MANUFACTURING QUALITY ASSURANCE

Permanent-magnet motors depend directly on magnetic field quality. Common manufacturing defects include weak magnets, pole spacing errors, magnet displacement, incorrect magnetization, partial demagnetization, rotor eccentricity, and cracked magnets.

A magnetic field mapper can identify these defects before final motor assembly. Benefits include reduced scrap, lower rework costs, improved yield, reduced torque ripple, improved efficiency, and lower NVH (Noise, Vibration, Harshness).



### APPLICATION 3: ENCODER MAGNET VERIFICATION

Encoder performance depends on highly accurate magnetic field distributions. Small deviations can create angle errors, position jitter, servo instability, and speed measurement inaccuracies.

A mapper allows manufacturers to verify pole count, pole spacing, harmonic distortion, magnetic angle accuracy, and supplier consistency. This is particularly important in robotics, industrial automation, automotive systems, and precision motion control.

### APPLICATION 4: MAGNETIC SENSOR DEVELOPMENT

Magnetic sensors depend on highly controlled magnetic fields. A mapper allows engineers to verify field magnitude, field direction, spatial gradients, sensor positioning, and stray field effects. This significantly shortens the gap between simulation and functional hardware.

### UNDERSTANDING ROI

Many organizations underestimate the cost of magnetic defects because the losses are distributed across multiple departments: engineering debugging time, additional prototype iterations, yield loss, rework, warranty claims, supplier investigations, and delayed product launches.

A magnetic measurement system often pays for itself not by measuring fields, but by eliminating these hidden costs.

#### Example ROI Scenario

Typical annual hidden costs distributed across departments:

Cost Category	Annual Loss
Engineering troubleshooting	€50,000
Prototype rework	€40,000
Production scrap	€60,000
Supplier qualification issues	€25,000
<b>Total annual losses (example)</b>	<b>€175,000</b>

A magnetic field measurement system that reduces even a portion of these losses can achieve payback within less than one year.

## HOW MAPPERS AND CAMERAS GENERATE FAST ROI

The return on investment depends much more on your business process than on the instrument itself. Companies usually achieve fast ROI when the mapper helps prevent expensive mistakes, reduce engineering time, or automate quality control.

1. **Reduce development cycles.** Eliminating even one or two prototype iterations — each costing thousands in labor and materials — can justify a significant portion of the investment.
2. **Catch manufacturing defects earlier.** Defects discovered after assembly are far more expensive than those found at the component stage. Finding issues before final assembly saves material costs, rework costs, and customer return costs.
3. **Increase production yield.** In many industrial environments, yield improvements of even fractions of a percent produce annual savings that exceed the instrument cost.
4. **Shorten troubleshooting time.** A field map provides direct evidence of what's happening magnetically. If engineering teams spend hundreds of hours annually on magnetic issues, the labor savings alone can be significant.
5. **Improve customer confidence.** Providing quantitative magnetic field characterization performed by industry standard and qualified measurement devices differentiates your product, supports premium pricing, reduces disputes, speeds qualification processes, and insures your reputation.

## WHAT PRODUCTION MANAGERS VALUE MOST

The most practical benefit is that a magnetic mapper or camera converts magnetic performance into a measurable production parameter. Many teams spend weeks trying to infer magnetic behavior indirectly from electrical measurements.

Instead of asking: *“Why is this motor underperforming?”* — you can ask: *“Which rotor has a pole-position error exceeding 0.2°?”*

That changes troubleshooting from an engineering investigation into a straightforward quality-control decision. For manufacturers of motors, encoder magnets, and precision magnet assemblies, a mapper often becomes the equivalent of a coordinate-measuring machine

(CMM) — except it measures the magnetic properties that ultimately determine product performance.

## THE STRONGEST BUSINESS CASE

The strongest case is usually not: *“This magnetic mapper/camera measures magnetic fields accurately.”* The strongest case is:

*“We spent 6 weeks diagnosing a torque-ripple problem. A mapper would have found the root cause in one day.”*

*“We scrapped €200,000 of rotors because the magnetization fixture drifted.”*

*“We rejected a magnet supplier after discovering a pole-position variation that was causing encoder failures.”*

When the discussion moves from measurement capability to money lost because of unknown magnetic defects, the purchase becomes much easier to justify.

A **magnetic field mapper** typically pays for itself by: **Measuring precisely and preventing bad decisions.**

A **magnetic field camera** typically pays for itself by: **Finding the root cause of magnetic problems much faster.**

*“That’s the core reason companies buy one: not because it measures magnetic fields, but because it dramatically shortens the time from “something is wrong” to “we know exactly why.”*

## CONCLUSION

Magnetic performance increasingly defines the success of modern products, particularly in electric vehicles, robotics, industrial automation, and sensing systems. Yet magnetic behavior often remains invisible throughout design and manufacturing processes.

Magnetic Field Mappers and Magnetic Field Cameras transform magnetic fields from hidden variables into measurable engineering parameters. The result is:

- Faster development
- Better simulation accuracy
- Improved production quality
- Lower manufacturing costs
- Faster troubleshooting
- Stronger customer confidence

Organizations that integrate magnetic measurement into their workflows gain a significant competitive advantage by identifying problems earlier, understanding root causes faster, and making better engineering decisions.

## ABOUT SENIS GROUP, SWITZERLAND

SENIS is a leading provider of advanced magnetic field measurement instruments. Every probe is individually calibrated in our ISO/IEC 17025-accredited laboratory, ensuring exceptional accuracy, traceability, and reliability. Visit [www.senis.swiss](http://www.senis.swiss) or contact [info@senis.swiss](mailto:info@senis.swiss).