# GeoDict

## The Digital Material Laboratory

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### Easy-to-use ▪ Powerful ▪ Accurate

**MATH**
**2 MARKET**

# INNOVATION THROUGH SIMULATION

The development of new materials and the improvement of already existing materials have been the foundation for technological progress since the beginning of mankind and are of essential importance for almost all branches of industry and fields of application in our society.

The claim to innovation, performance, and durability of a product is mainly determined by its material properties. An in-depth understanding of these properties is the basis for targeted material development and a high-quality end product. To date, extensive experimental tests and prototype development have been the predominant way to implement materials with specific characteristics. In addition to the cost and time involved, laboratory tests often destroy samples and render them unusable for the analysis of other material properties.

Simulations are already being used successfully in many areas of product and process development, as they reduce development time and costs considerably. Computer-aided simulations in material development pave the way for a real technological and economic breakthrough.

## The Digital Material Laboratory

The development of the GeoDict® software answers the urgent need for digital solutions in the area of material design and analysis. Whether for newly designed or existing materials, simulations offer a qualitative and quantitative understanding of the geometric and physical properties of materials.

Stunning insights into the structure and behavior of materials are gained thanks to multi-scale analysis down to the nanometer range, to 3D visualization of real structures and to repeatable, non-destructive tests.

Some of the properties assessed by simulation are extremely difficult - if not impossible - to measure and to understand in the laboratory. For this reason, the use of simulations complements and completes laboratory measurements, contributing not only detailed information, but also new findings.

With GeoDict®, our customers have at their disposal a digital material laboratory in which they digitally map their entire material development workflow - from importing the material data, as scans or through defining parameters, to visualizing and automatic reporting of the simulation results.

## GeoDict® - A competitive advantage overview

- **Reduce development, prototyping, and production costs, as well as time-to-market**

- **Develop target materials and products to fit specifications**

- **High flexibility in development due to digital feasibility studies, individual parameter studies and cost-efficient digital testing of customer-specific requirements**

- **Enhance the quality of materials and complete products at a fraction of current cost**

## *NEW in GeoDict® 2019: Artificial intelligence for identification of binder and fibers, and fiber distribution analysis

**Math2Market is winner of the „FILTREX Innovation Award 2019"**
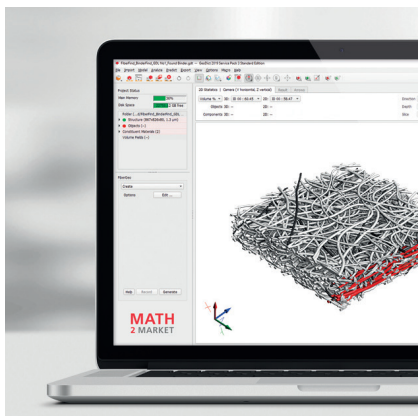


**GeoDict® 2019 - especially the new module FiberFind-AI, which is based on artificial intelligence - provides the tools to better understand CT images and paves the way for the materials technology of the future.**

On the nonwoven microstructures modeled in GeoDict®, a neural network is trained that is able to recognize binder with FiberFind-AI and to identify fibers directly from µCT scans of real nonwovens. Once all fibers have been identified, detailed insights into the properties of fibers in a material can be gained. Fiber properties include fiber orientation after deposition in a nonwoven, fiber diameter and length distribution in a glass fiber-reinforced plastic, or local deformation of fibers in weaves.

With FiberFind-AI, nonwoven manufacturers can develop novel, optimized products while greatly reducing prototypes and experimental costs and time.

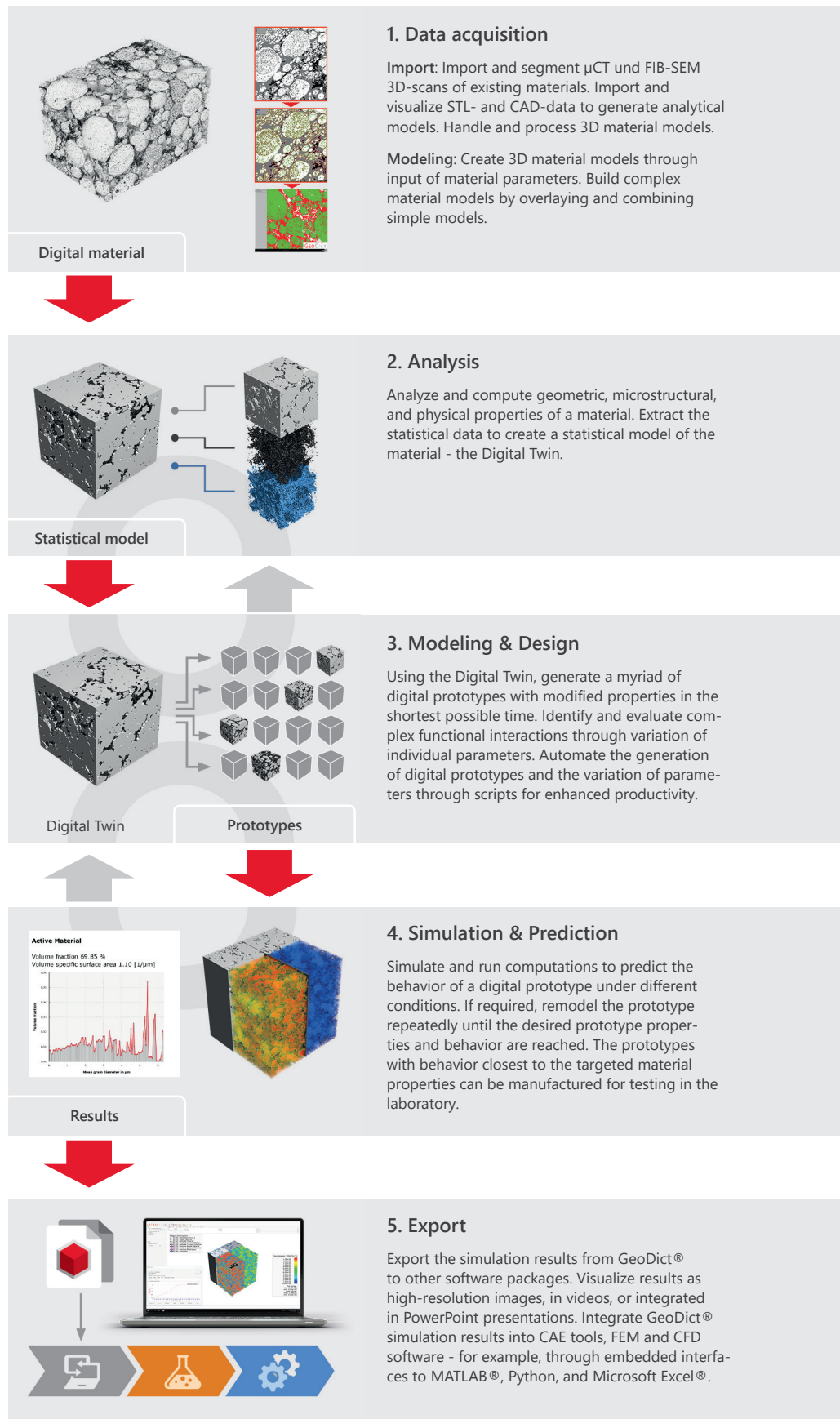# GeoDict® Workflow for Material Development

## Easy-to-use

- User-friendly, intuitive graphical user interface
- Seamless integration into existing IT infrastructure
- Complete automation and repeatability - thanks to MATLAB® and Python
- Voxel grid makes elaborate meshing unnecessary

## Advanced and powerful features

- Analysis, property prediction, and visualization directly on computed tomography (CT) scans and focused ion beam-scanning electron microscopy (FIB-SEM) scans
- Structure generators: fast, realistic modelling of microstructures with random elements that enables serial digital testing
- Artificial intelligence for identification of binder and fibers, and fiber distribution analysis
- High storage efficiency: simulations on structures of 64 billion voxels and more are possible on single computers or in clusters

## Accurate property prediction

- Accurate prediction of material behavior based on the material microstructure
- Unmatched range of physical parameters predicted by GeoDict®
- Prediction of complex material behavior such as large deformations, and damage as well as fracture behavior and fatigue at microstructure level
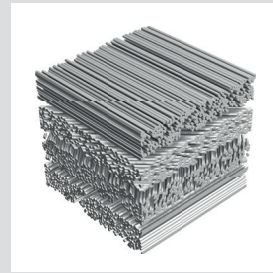
**Digital material**

### 1. Data acquisition

**Import**: Import and segment µCT und FIB-SEM 3D-scans of existing materials. Import and visualize STL- and CAD-data to generate analytical models. Handle and process 3D material models.

**Modeling**: Create 3D material models through input of material parameters. Build complex material models by overlaying and combining simple models.

**Statistical model**

### 2. Analysis

Analyze and compute geometric, microstructural, and physical properties of a material. Extract the statistical data to create a statistical model of the material - the Digital Twin.

**Digital Twin** **Prototypes**

### 3. Modeling & Design

Using the Digital Twin, generate a myriad of digital prototypes with modified properties in the shortest possible time. Identify and evaluate complex functional interactions through variation of individual parameters. Automate the generation of digital prototypes and the variation of parameters through scripts for enhanced productivity.

**Results**

### 4. Simulation & Prediction

Simulate and run computations to predict the behavior of a digital prototype under different conditions. If required, remodel the prototype repeatedly until the desired prototype properties and behavior are reached. The prototypes with behavior closest to the targeted material properties can be manufactured for testing in the laboratory.

### 5. Export

Export the simulation results from GeoDict® to other software packages. Visualize results as high-resolution images, in videos, or integrated in PowerPoint presentations. Integrate GeoDict® simulation results into CAE tools, FEM and CFD software - for example, through embedded interfaces to MATLAB®, Python, and Microsoft Excel®.
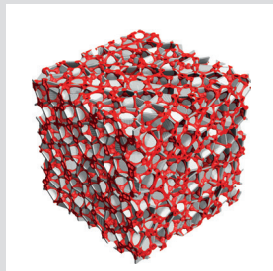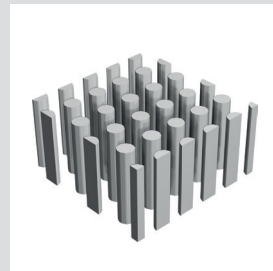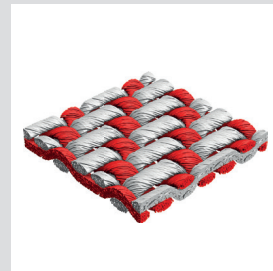
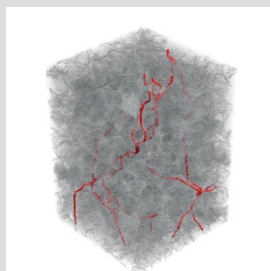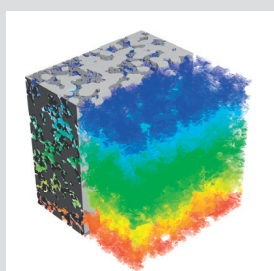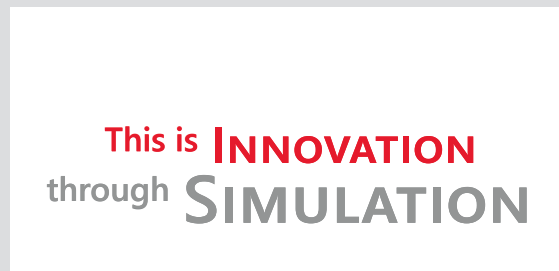*Exemplary GeoDict® workflow for the development of a battery*

IMPORTGEO



FIBERGEO
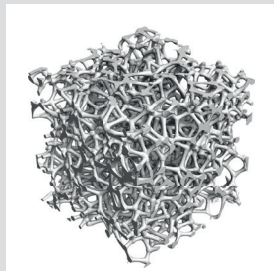


FOAMGEO
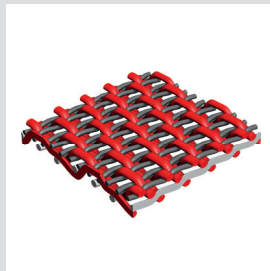


WEAVEGEO



GRIDGEO
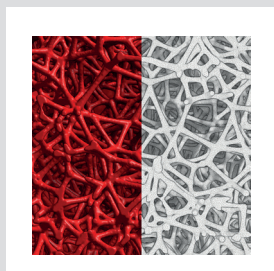


MESHGEO



EXPORTGEO



PORODICT

This is **INNOVATION**
through **SIMULATION**
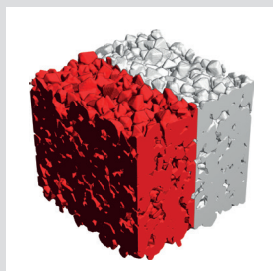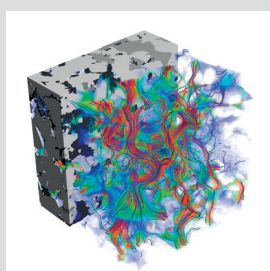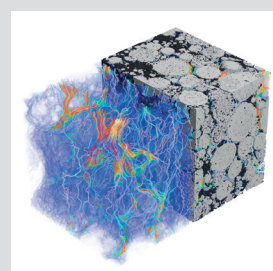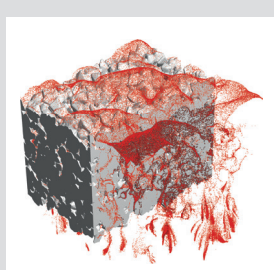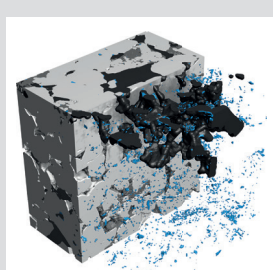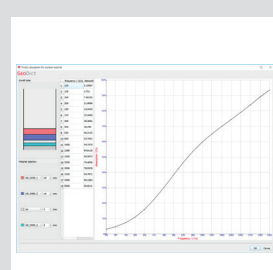


DIFFUDICT
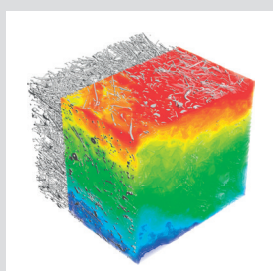


CONDUCTODICT



FLOWDICT



ELASTODICT



ADDIDICT



SATUDICT
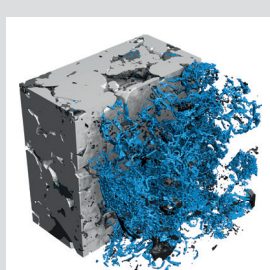


ACOUSTODICT
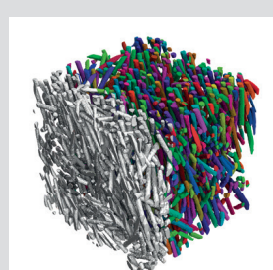


FIBERFIND

# GeoDict



PaperGeo



GrainGeo







PleatGeo



MatDict
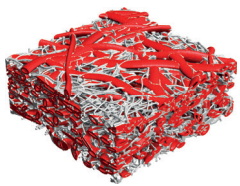


BatteryDict
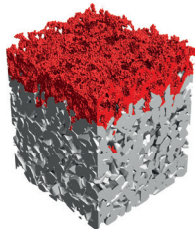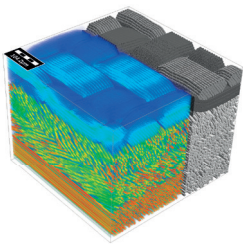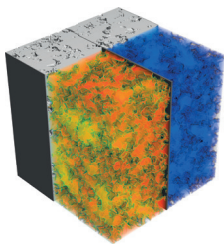






FilterDict Media & Element







GrainFind

## GeoDict® Modules

GeoDict® is used worldwide for R&D in industrial and academic settings mainly in the fields of filtration, structural materials, electrochemistry (batteries and fuel cells) and digital rock physics.
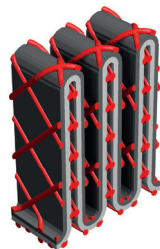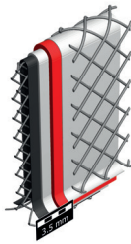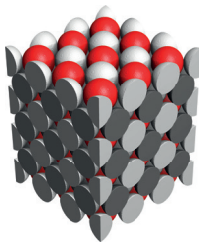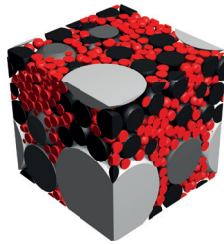
The modular setup of GeoDict® is essential to its versatility and adaptability to the specific requirements of diverse applications. GeoDict® is a customized solution, tailored to the development or research task of the user.
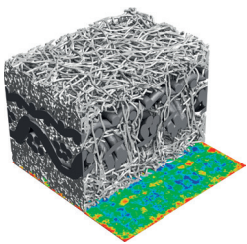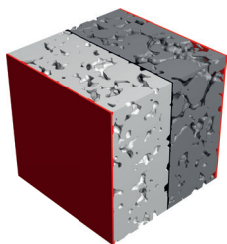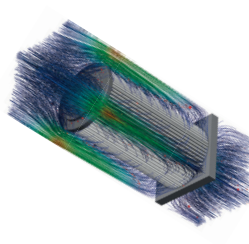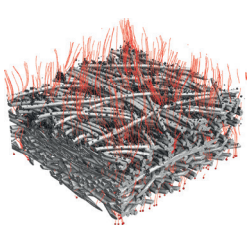


# GeoDict® in Industrial and Academic Settings

## Filtration

Filters are developed for the requirements of their specific field of application thanks to state-of-the-art simulation methods. With GeoDict®, filtration processes can be simulated and filters for particle, gas, and liquid filtration are designed and improved.

From the analysis of µCT and FIB-SEM 3D-scans, GeoDict® delivers a detailed insight into the microstructure of existing filter material, identifies fiber and binder, and quantifies material properties such as fiber diameter, fiber orientation, fiber and binder percentage, basis weight, or the orientation of individual material layers. For air, gas and liquid filtration, GeoDict® performs simulations of both single-pass and multi-pass tests with a variety of test dusts. The initial pressure drop, filter efficiency, fractional efficiency, and many other filter media properties are computed. GeoDict® also provides detailed data on particle movement and deposition in filter media, and on filter clogging.
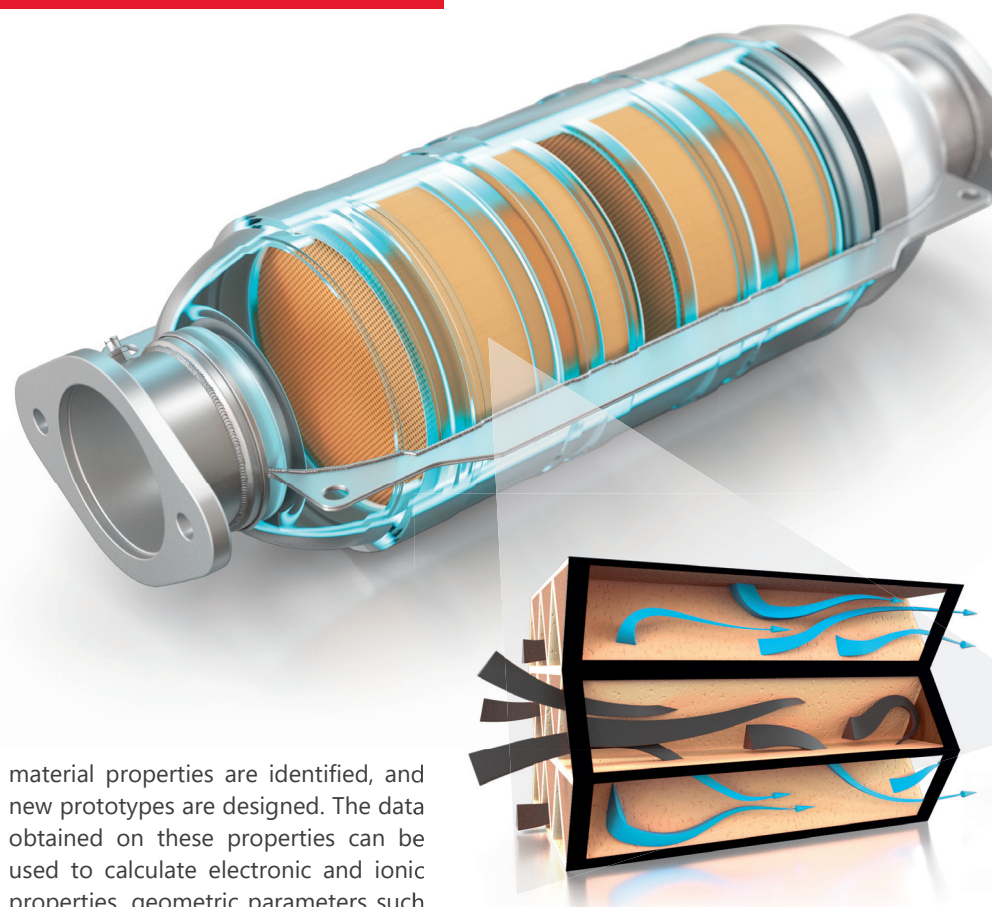
Varying the statistical parameters for their generation, numerous digital prototypes are created fast and efficiently. Such variations result in changes in material properties and performance of the filter medium that are simulated and computed on large series of digital prototypes.

## Electrochemistry

The global growth of the economy and the population is generating an increasing demand for energy and the associated challenge of its intermediate storage. Batteries and fuel cells play a central role in energy storage and use.

GeoDict® simulations represent a cost- and time-saving alternative to real physical experiments in the development and optimization of energy storage media. In GeoDict®, 3D models of materials used in batteries (LIB, SSB, RFB) or fuel cells (PEM, SOFC) are digitally constructed, the relevant material properties are identified, and new prototypes are designed. The data obtained on these properties can be used to calculate electronic and ionic properties, geometric parameters such as porosity, pore size distribution and tortuosity, and saturation, diffusion, and flow parameters. All these parameters can be varied and adjusted in the digital prototypes until the simulation results meet the requirements of the energy storage media.

For batteries, the charging and discharging behavior as well as specific ageing mechanisms can be simulated to optimize the service life. For fuel cells, parameters such as thermal conductivity, thermal flow, temperature distribution or the capillary pressure curve can be determined. In addition to flow parameters such as permeability, the mechanical deformations of individual layers or material phases can also be calculated.

## Digital Rock Physics

Determination of the physical properties of reservoir rocks is one of the key steps in integrated reservoir modeling that lead e.g. to (i) the estimation of the oil/gas reserves and (ii) the prediction of future production profiles of an oil/gas reservoir. Reservoir modeling is the tool of the oil and gas industry to decide on the production and development of reservoirs along with the substantial investments that are associated with these decisions.

Digital Rock Physics (DRP) consists of reliable techniques that significantly save time and costs compared to conventional laboratory experiments. DRP determines the physical properties of rocks through numerical simulations on 3D scans of rock samples in a short time. GeoDict® simulations map the complete DRP workflow: 3D images of reservoir rocks are analyzed in GeoDict® and the petrophysical properties are computed. GeoDict® calculates geometrical, electrical, and mechanical parameters as well as flow parameters.

DRP simulations with GeoDict® are an excellent complementary technique to laboratory experiments and serve as an instrument for quality assurance of laboratory experiments and vice versa.

## CUSTOMER SERVICE & SUPPORT

### Structural Materials

The determination of the properties of structural materials plays an essential role in the development of innovative composites, metals, ceramics and foams, and is the only way to tailor them for an specific application and exploit their full potential.

GeoDict® offers fitting solutions for the determination of mechanical and physical parameters such as anisotropic stiffness tensor, thermal and electrical conductivity or permeability. Even large deformations as well as fracture behavior at the microstructure level can be mapped.

GeoDict® provides a comprehensive tool for digital material development that combines powerful structure generators for foams, semi-finished fiber products and grain structures, and the ability to import CT scans, analyze them and then use them in simulations. It enables the development of a new generation of advanced materials by gaining unprecedented insights into the microstructure. Development costs are significantly lowered by the reduction in the number of experiments and prototypes needed. In addition, digital materials can be developed and tested that cannot be produced without major adaptations or investments. GeoDict® satisfies the highest scientific demands, for instance through its ability to carry out individual parameter studies.

An intensive exchange of information, trainings, workshops and our annual User Meeting ensure the transfer of know-how for our customers and partners and the same high-service standard for all GeoDict® users. In complex projects and applications, we support our customers with advice and project work, and with our service partners, offer them prompt help and support.

#### Overview of our services

- Software development with annual releases and regular updates

- Extension and individual customization with Python as script language

- Distribution and licensing of GeoDict®

- Project work in cooperation with manufacturers of µCT-scanners and µCT-scan service providers

- Scientific project work, customer support and consulting

- User training in form of tutorials, workshops, short courses and individual trainings

- Information exchange and presentations at technical conferences and exhibitions and user meetings
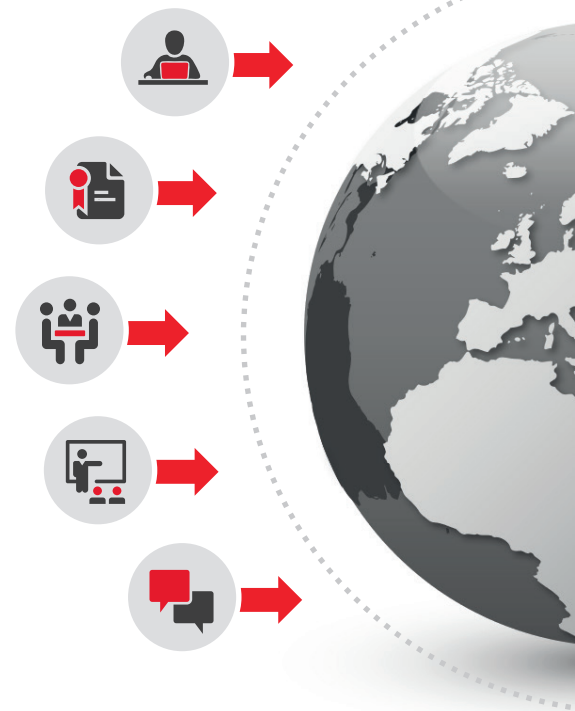
#### Service partners worldwide

| | | |
|---|---|---|
| Germany | Math2Market GmbH | www.math2market.de |
| China | Flight Technology CO., LTD. | www.lcdfly.com |
| | Pan Information Technology (Shanghai) Co., Ltd. | www.pan-i.com |
| Japan | SCSK Corporation | www.scsk.jp |
| South Korea | Trinity Engineering CO., LTD. | www.trinity-eng.co.kr |
| Brasil | Tennessine Instrumentação Analítica | www.tennessine.com.br |
| Taiwan | Pitotech Co., Ltd | www.pitotech.com.tw |

### GeoDict® - Licensing flexibility

| | License Type | Description | Maintenance (Updates and Support) |
|---|---|---|---|
| **1** | Purchase | unlimited time license | 1 year included, afterwards cost-effective renewal |
| | or | | |
| | Lease | limited time license | defined by lease period |
| **+** | | | |
| | | | HPC* / Cloud: |
| **2** | Node-locked | static license, limited to a specific workstation | no |
| | or | | |
| | Floating | local server-based license management | yes |

*\* Cluster-based high performance computing*

# Math2Market - The Company

GeoDict® combines modern science and powerful software development into a user-friendly solution for innovative material research and development in industry and academia.

Math2Market GmbH was founded in September 2011 by three members of the GeoDict® software development team as a spin-off from the Fraunhofer Institute for Industrial Mathematics (ITWM, Institute für Techno- und Wirtschaftsmathematik) in Kaiserslautern, Germany. Some of the founders had been working on the software since its inception in 2001. Today, Math2Market has a workforce of over 40 employees at its Kaiserslautern site and, with the software GeoDict®, is one of the leading providers of digital solutions in the field of materials research and development.

Over 150 large companies from various industries, universities, and research institutes worldwide simulate with GeoDict® to develop innovative materials and optimize their material development processes. With our unique pool of top mathematicians, physicists, geologists, engineers, and computer scientists, we believe in making available to our clients the benefits of cutting-edge, university-level research that can be utilized by non-experts using our software GeoDict®.

Our customers benefit from our comprehensive services, including regular updates of GeoDict®, intensive customer care and consulting, as well as training and reliable support by our experts in their respective fields.

Math2Market cooperates in diverse ways with international partners from industry and academia and participates regularly in scientific congresses and technical trade fairs with innovative contributions.

*„We work with our customers to digitize their processes and enable them to accelerate research and development with highly efficient and user-friendly software. In the age of rapid technological development, GeoDict helps our customers to bring their groundbreaking ideas for tomorrow's materials to life today."*

*Andreas Wiegmann, PhD / CEO / Math2Market GmbH*