

# MACHINE LEARNING, AI, & UNCERTAINTY QUANTIFICATION SOFTWARE



**SmartUQ is a Machine Learning (ML) and AI tool optimized for engineering applications from ideation and design to manufacturing and sustainment. By providing powerful tools and highly accurate models with user-friendly GUIs and APIs, SmartUQ makes it easy to perform predictive modeling, optimized sampling, uncertainty quantification, and model calibration.**

# ABOUT SMARTUQ

From Fortune 500 manufacturers to startups and engineering consulting firms, SmartUQ's best in class predictive modeling accuracy helps our customers go beyond analysis to bring uncertainty into the decision-making process.

SmartUQ was originally developed to solve UQ challenges for a leading jet engine manufacturer because their previous tools could not handle the complexity, scale, and high-dimensionality of their problems. Since then, SmartUQ has become a user-friendly general ML and AI tool. We now have users across industry and government in Automotive, Aerospace & Defense, Turbomachinery, Heavy Equipment, Medical Device, Semiconductors, Consumer Electronics, Energy, and Oil & Gas.

The team is headed by world-class experts in statistics and engineering who take pride in creating game-changing solutions where no off-the-shelf solution exists. Our software has helped our customers solve some of their most difficult analytics problems saving millions of dollars and thousands of hours of work.

## EASY TO USE SOFTWARE

**User-Friendly GUI** – Powerful, yet intuitive, SmartUQ is designed for Engineers and Data Scientists alike. SmartUQ's clean, straightforward user interface, including software wizards, makes performing complex analyses easier than ever before.

**Integration** – Analytics software is only as powerful as it is compatible with other systems. With SmartUQ's application programming interface (API), you can seamlessly integrate SmartUQ tools into your workflow.

- SmartUQ's API significantly reduces time spent on performing analyses while still providing the full benefits of its GUI.
- SmartUQ also has built-in integrations with CAE tools.

**Automated Machine Learning** – With an existing data set, a connected simulation model, or a digital twin, SmartUQ runs, builds, and compares predictive models until it meets your accuracy requirements.

# SMARTUQ SOLUTIONS FOR DIFFICULT MACHINE LEARNING PROBLEMS

From initial design to telemetry analysis, SmartUQ helps our Fortune 500 customers reduce the time, cost, and risk of solving complex data and engineering problems. With an application agnostic toolset, SmartUQ's versatility allows our users to find solutions to their most complicated problems from physical and simulation modeling to new technologies such as Digital Twin – Digital Thread environment. With problems big or small, below are some of the many ways SmartUQ's software helps our customers achieve a competitive advantage.

## Sensitivity Analysis

- Accommodate High Dimensionality
- Reduce Computational Demand
- Understand the Effects of Interactions Between Inputs

## Uncertainty Analysis

- Uncertainty Propagation
- Robust Design Processes

## Model Calibration & Validation

- Tune Models to Match Data Better than Other Methods
- Quickly Investigate Model Form Errors
- Simulation Validation under Uncertainty

## Real System Applications

- Controllers
- Virtual Sensors
- Prognostics and Diagnostics
- Understanding Noisy Data



## Manufacturing Analytics

- Predictive Six Sigma
- Manage Uncertainty in Additive Manufacturing
- Reduce Part-to-Part Variability

## Digital Twin / Digital Thread Applications

- Early Parametric Trade Studies
- Manage and Assess Uncertainty Budgets
- Development of the Authoritative Truth Sources

## Testing & Evaluation Planning

- Improve Uncertainty Budgets
- Select Optimal Test Points
- Identify Critical Inputs

## Acceleration of Simulation Efforts

- Efficient Design Space Exploration
- Minimize Number of Runs



# SMARTUQ SOLUTIONS FOR EXECUTIVES & MANAGERS

## Executives

### Competitive Advantage

The best way to gain a competitive advantage is to extract meaningful value from your data through predictive modeling. With SmartUQ's advanced analytics and machine learning technology, our clients have saved millions of dollars and thousands of hours of work.

### More Productive Across All Departments

In the past, data have been siloed to one department, limiting its potential insight and value. With SmartUQ, you can develop predictive models with your design team, update with your test and evaluation crew, and share those results with customers as proof of the reliability and durability of your product.

### Meeting Government Regulations

Government regulatory agencies like the Department of Defense, the Federal Aviation Administration, and the Food and Drug Administration have developed and continue to evolve guideline documents for the inclusion of numerical simulation models as a credible source of evidence for meeting regulatory requirements. The guideline documents recommend manufacturers to include model Verification, Validation and Uncertainty Quantification (VVUQ) as part of their numerical analysis reports. The SmartUQ staff have strong expertise in the field of UQ and understand the role of UQ in the VVUQ processes. SmartUQ's experts can help integrate UQ into your company's engineering workflow, in accordance with the government regulatory guidelines.



## Managers

### Better Decision Making

Develop a disciplined, consistent approach to quantifying how well the system meets the requirements subject to real-world variabilities by forecasting risks in domains such as product performance, cost, and schedule to support better decision making.

### Reduce Maintenance Downtimes & Cost

By enabling probabilistic analysis of the reliability of components, you can schedule maintenance on quantified risk-based metrics as opposed to static requirements such as a fixed number of operational cycles.

### Data-Driven Decision Making

Industry is moving towards data-driven engineering where it has become increasingly important to manage and understand data coming from a multitude of sources such as sales, design, and manufacturing. By applying ML and Uncertainty Quantification methodologies, you can make your decisions with confidence by knowing how much risk is involved. By integrating data from different departments, you and your team can understand the risks at each decision-making step and potential paths to mitigate them.

# SMARTUQ SOLUTIONS FOR ENGINEERS & DATA SCIENTISTS

## Engineers

### Designed for Engineers

With a user-friendly GUI, SmartUQ software is designed for engineers to quickly and intuitively perform powerful analytics.

### Save Time and Costs

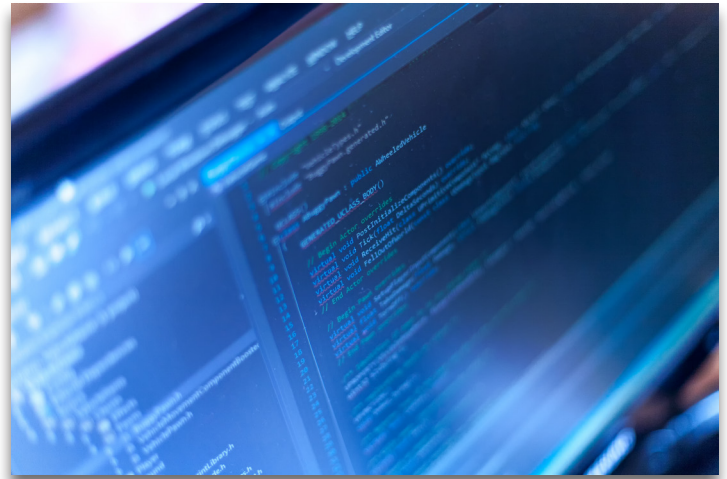
You can replace your time-consuming simulation runs and physical tests with SmartUQ's wide-ranging library of scenario-tailored predictive models and make predictions or run advanced analytics in a fraction of the time.

### Improve Quality and Reduce Risk

With advanced analytics at your fingertips, get accurate information to make important decisions such as how to maximize your product's reliability and durability. For example, using SmartUQ statistical calibration feature, you can validate that your simulation agrees with reality, thus reducing model form uncertainty.

### Automate Your Workflow

In addition to our user-friendly GUI, SmartUQ has a full-featured Python API for automating engineering analytics workflows and interfacing with other tools. SmartUQ also has direct integrations with commercial simulation packages.



## Data Scientists

### AI and Machine Learning Models

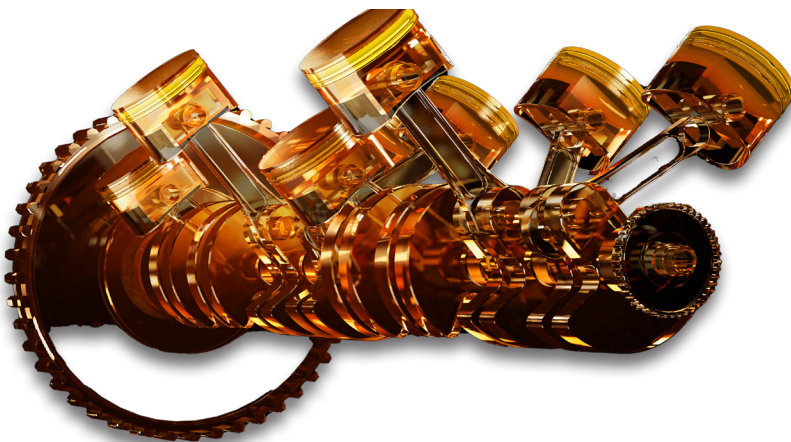
SmartUQ's wide-ranging library of scenario-tailored predictive models can solve a plethora of difficult problems. By overcoming many of the previous limitations in predictive analytics, our methods can tackle problems of much larger size and higher degrees of complexity than any previous tools for engineering applications.

### Powerful Analytics

SmartUQ can perform predictive analytic and Uncertainty Quantification tasks such as Statistical Calibration, Sensitivity Analysis, Inverse Analysis, and Uncertainty Propagation. Because the predictive model can quickly make predictions, you can drastically reduce the number of time-consuming simulation runs, getting actionable results in record time.

### Empower Your Team and Yourself

With SmartUQ's user-friendly GUI and award-winning training, your team of engineers and data analysts can become empowered to build predictive models and perform analyses on their own and thus, freeing your time for more complex analyses.

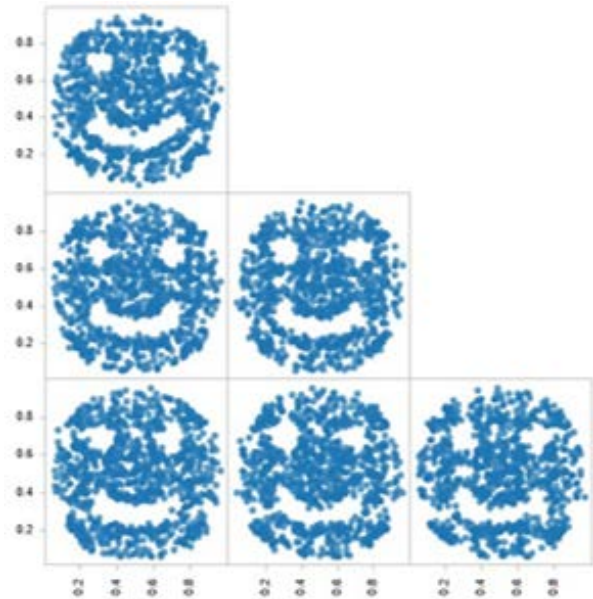


# DOEs & DATA SAMPLING

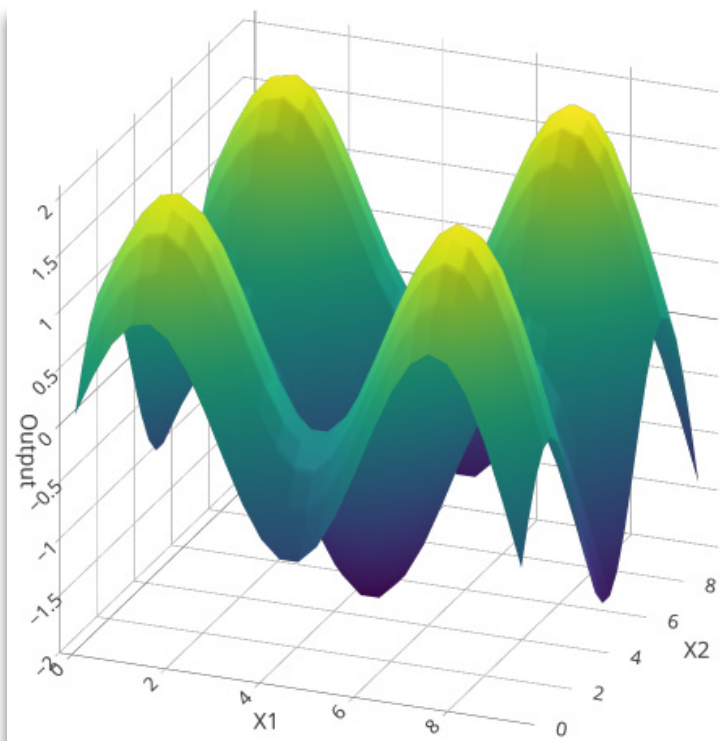
## Efficient Sampling of Design Space –

SmartUQ's design of experiments (DOEs) are designed to handle modern scenarios, such as high-dimensional inputs, continuous and categorical inputs, constrained design space, and iterative DOEs suited for applications where minimizing the amount of simulations and physical testing is essential.

**Data Sampling** – SmartUQ's data sampling tools can divide large data sets to mimic a space-filling DOE consisting of subsets of the full data set. The tool takes existing input-output data pairs and selects the points that best represent the design space.



**Though it depends on the specifics of the problems being solved, SmartUQ has reduced the number of necessary simulation points by up to 75 percent over our customers' previous best practices.**



## Data Exploration & Visualization –

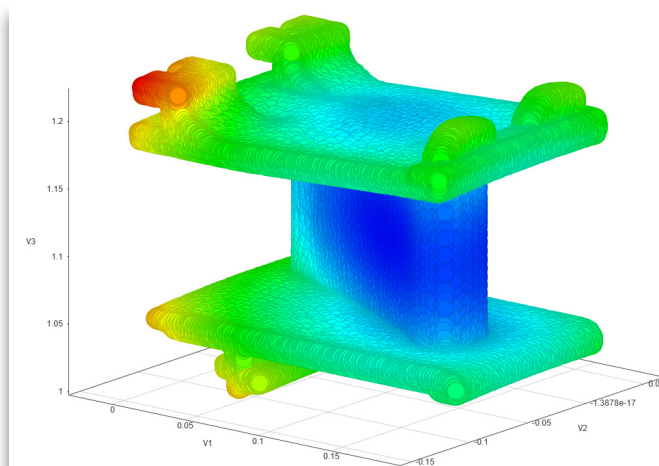
With a range of two-dimensional to four-dimensional plots with spatial and temporal components, SmartUQ enables you to explore your data and quickly recognize patterns that may emerge. In a few clicks, you can visualize large data sets and discover underlying relationships and potential outliers.

# MACHINE LEARNING & PREDICTIVE MODELING

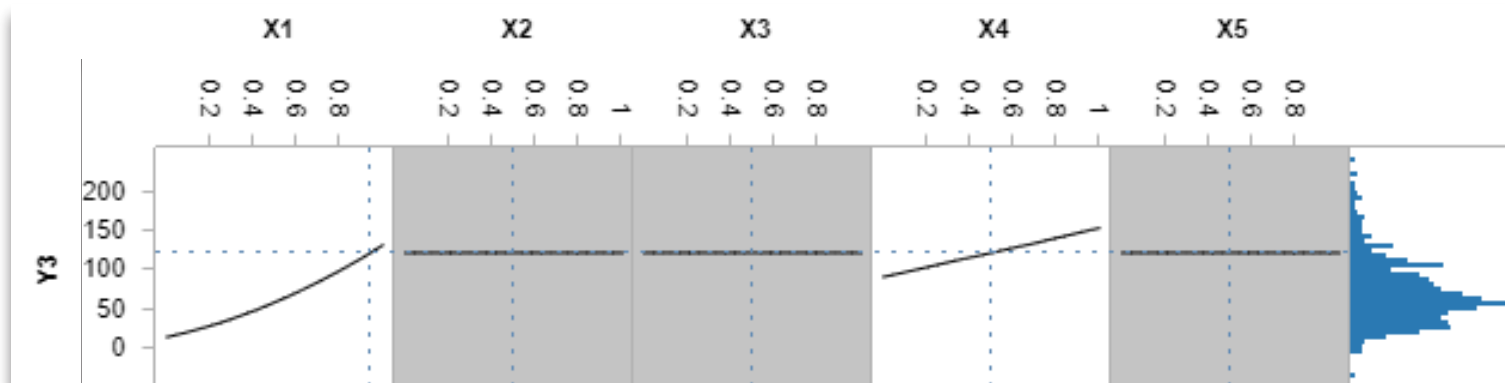
The library of ML and predictive modeling options in SmartUQ covers a wide range of scenarios including predictive modeling for discrete and continuous inputs, spatial inputs, functional/transient responses, classification tasks, high dimensional problems, and very large sample sizes.

SmartUQ's ML and predictive models provide an optimal balance of speed and accuracy resulting from advanced modeling algorithms optimized for engineering applications.

SmartUQ has a flexible set of advanced predictive analytics and machine learning algorithms, including Gaussian process and kernel methods, neural network and deep learning, additive models, penalized regression, and response surface models.



**3D Field Prediction** – With direct prediction of spatially and/or temporally distributed data, SmartUQ's functional predictive modeling enables large-scale interpolation between the results, such as CFD/FEA or physical testing much faster than running a simulation or experiment. SmartUQ's varying geometry ML models extend spatial field predictive modeling capabilities to situations where the number and location of the spatial points can vary between cases.



**Input/Parameter Screening** – One of SmartUQ's innovative predictive models removes uncorrelated inputs to more accurately fit a complex model with nonlinear behavior, resulting in reduced input dimension space and sampling requirements. The Multiview plot shows the individual relationships between the input parameter and the output parameter. The grey boxes are uncorrelated inputs, and the blue histogram is the uncertainty propagation of the output.

# FROM JET ENGINES TO MEDICAL DEVICES

The following demonstrations were run on a typical Windows laptop. The studies show the incredible power, versatility, and accuracy of SmartUQ with different levels of data size and simulation.

## CASE STUDY: FORTUNE 100 JET ENGINE DESIGN COMPANY HIGH DIMENSIONAL PREDICTIVE MODELING



### CHALLENGE

Turbine engines, like other complex systems, are composed of many subsystems featuring a wide variety of physics and extreme behavior. From a simulation and analysis perspective, this means there are many input dimensions, and the system suffers from the curse of dimensionality: i.e., it requires an exponential increase in sampling to cover the design space for the same level of resolution.



### SOLUTION

With existing tools, the jet engine OEM couldn't scale up their engine performance exploration and characterization efforts without an exponential increase in simulation resources. Particularly challenging was high fidelity CFD simulation of transient thermal events.



### RESULTS

By developing novel, faster and more efficient DOE and predictive modeling tools, SmartUQ was able to help make sampling and simulation requirements manageable while maintaining and/or improving model accuracy.

## CASE STUDY: FORTUNE 500 MEDICAL DEVICE COMPANY DEVELOPMENT OF CUT-PATTERN SPECIFICATION FOR A SLOTTED TUBE



### CHALLENGE

Slotted tubes play an important role in the medical device industry as the mechanical backbone for various device designs. Defining specifications for the slot cut patterns can be difficult due to precision requirements for validation tests and the expense of manufacturing test units. Modeling fidelity required to capture fatigue at narrow joints makes computational analysis difficult as well.



### SOLUTION

The medical device company developed a workflow using SmartUQ to successfully calibrate parameters in their fatigue model to better match a limited set of specimens they tested. They were also able to construct a discrepancy model in SmartUQ to map model form error in their computational model.



### RESULTS

Using the calibrated emulator corrected with their discrepancy model, as well as emulator variance information that captured model uncertainty, the medical device company was able to set geometric specifications for key slot cut-pattern parameters that can be used as acceptance criteria in a manufacturing environment.



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