



Automate engineering processes at scale

pSeven

overview

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pSeven product line

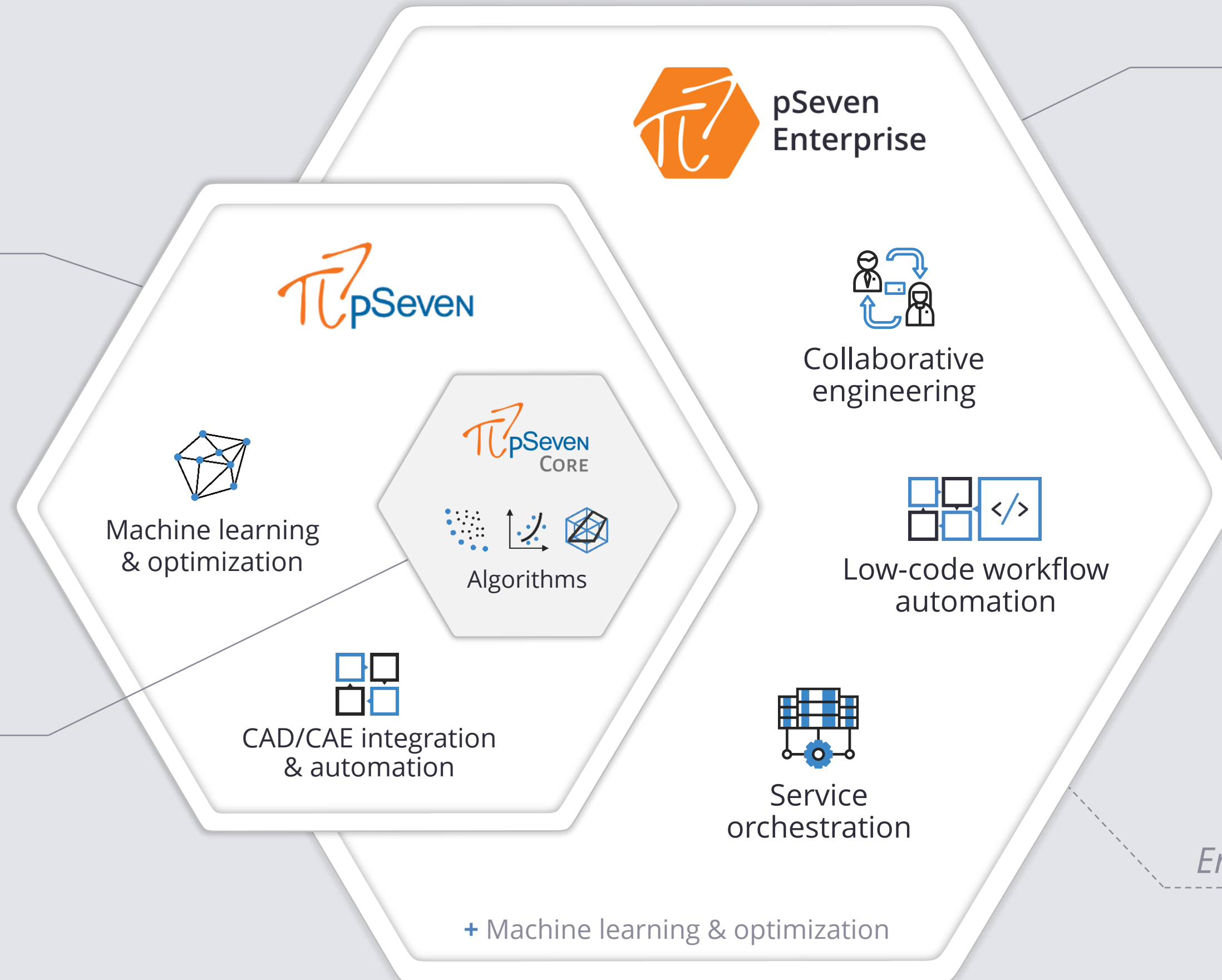


Desktop application
For local engineering tasks
& product development

10% design lead time reduction



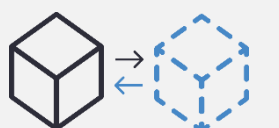
Python library
For scientific research
& software development



Cloud-native platform
For engineering automation
at enterprise level

Up to 3x productivity gain

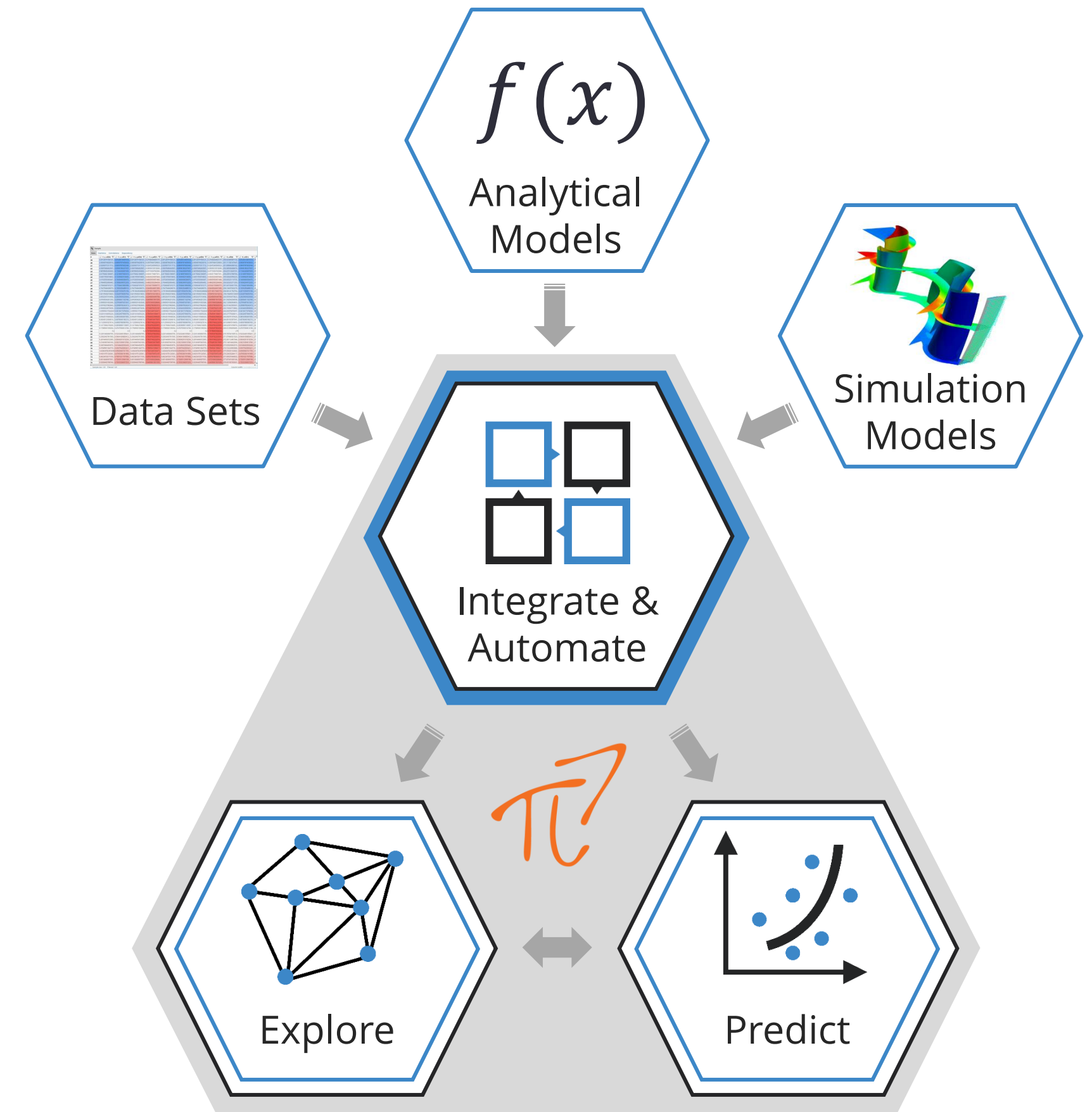
Enable



Digital Twins

Integrate, Explore & Predict

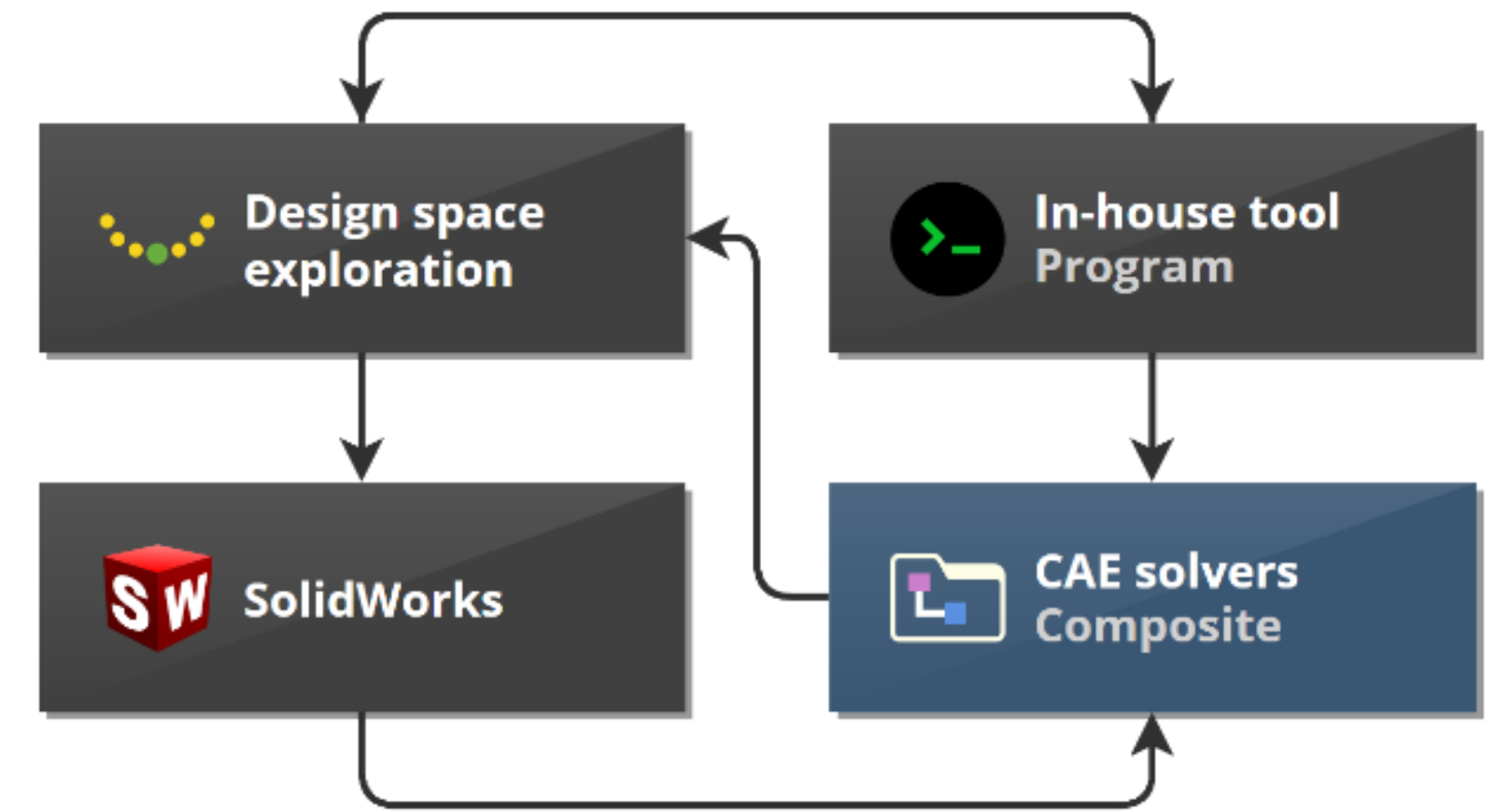
- pSeven is developed to:
 - **Automate** complex product design processes and **integrate** all external software and data into a single workflow
 - Solve engineering problems with a complete toolset for **Design Exploration** and **Predictive Modeling**





Process automation in pSeven

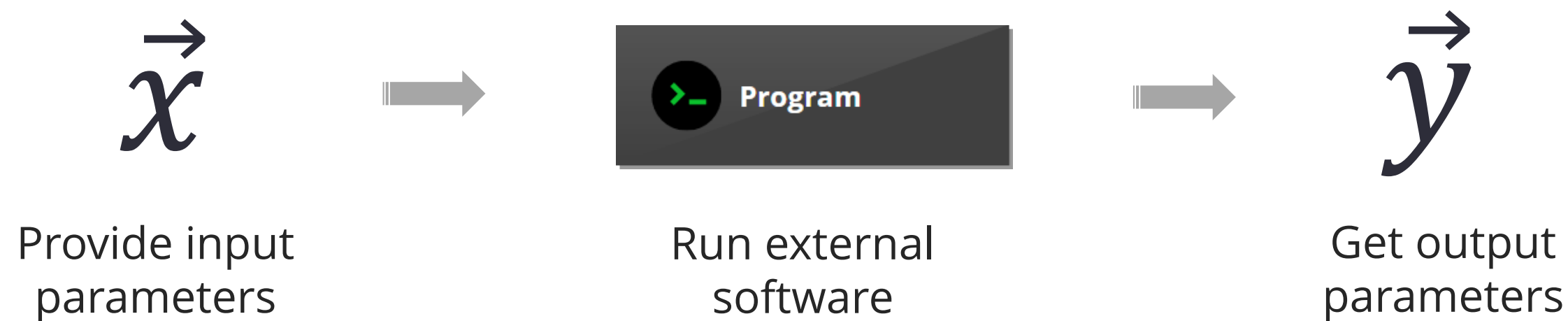
- Design process in pSeven is represented as a **sequence** of computations with defined **execution** order. This is called a **workflow**.
- Workflow consists of blocks, connections and parameters that provide:
 - Intuitive and visual **definition** of complex computations
 - Implementation of logic operations and nested loops
 - **Parallel** and **remote** execution
 - **Data** reuse and caching

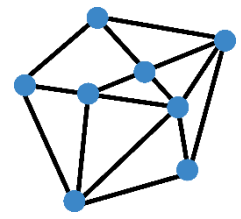




External software integration

- pSeven is a vendor-neutral platform and allows engineers to integrate any CAD/CAE software packages their company uses into a single workflow.
- pSeven workflow includes two kinds of integration blocks:
 - **Direct integration** blocks — program-specific blocks, easy to configure.
 - **Generic integration** blocks — allow integration using any program's command line interface. Provide greater flexibility than direct integration blocks, but often require some scripting or manual command input.





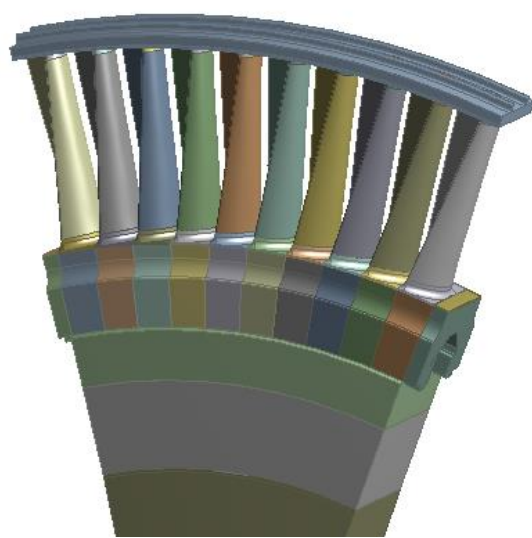
Design Exploration in pSeven

■ Design Exploration allows engineers to:

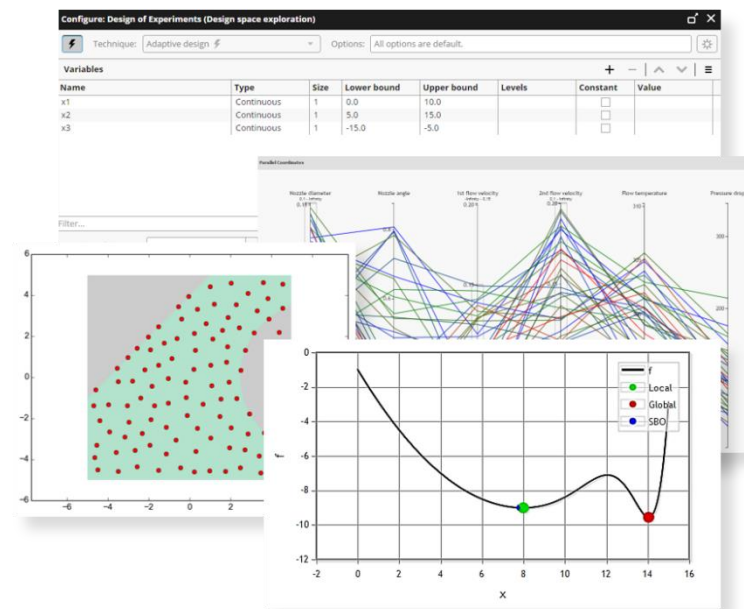
- Develop **trust** in their models
- Explore design **alternatives**
- Perform **trade-off** studies
- **Discover** bottlenecks
- **Identify** models
- Set **goals**

“**Design Space Exploration** is both a class of quantitative methods and a category of software tools for **systematically** and **automatically** exploring very large numbers of design alternatives and identifying **optimal** performance parameters.”

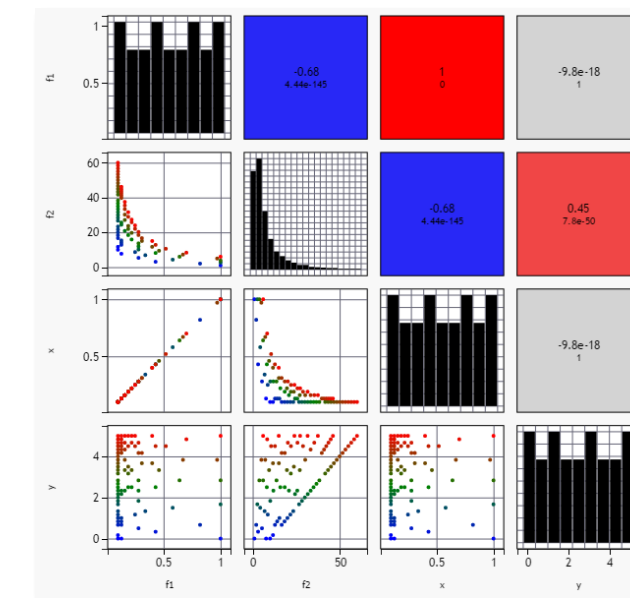
- B. Jenkins, Ora Research



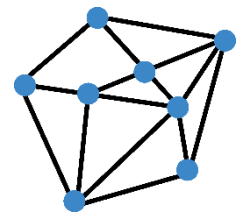
Create model



Apply Design
Exploration tools

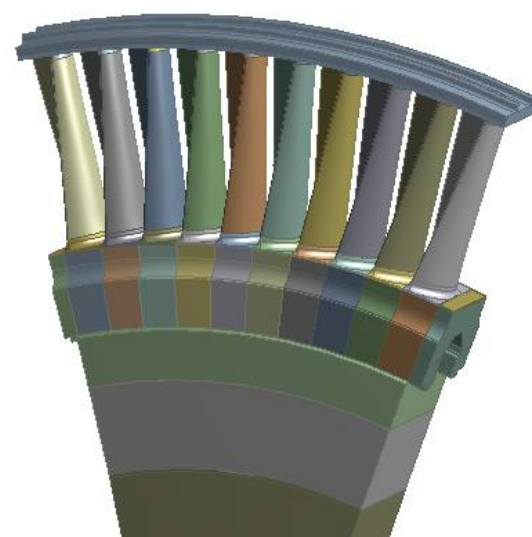


Make decisions
based on numbers

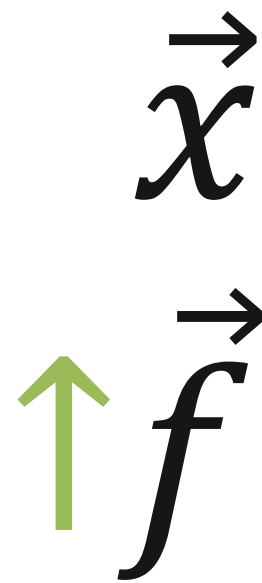


What is Design Optimization?

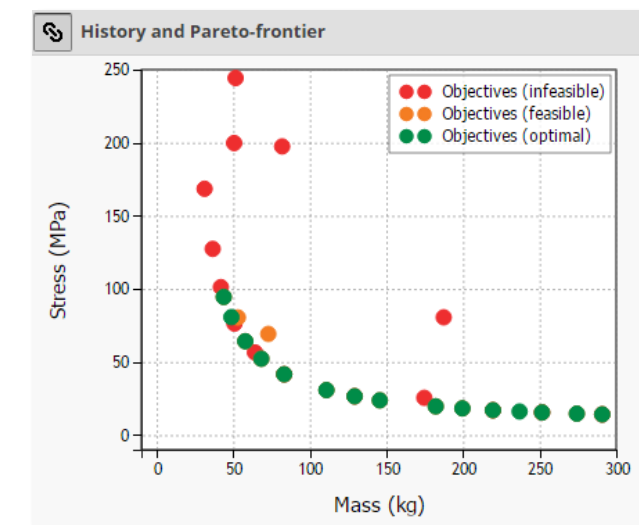
- Manual design optimization appeared at the same time as the product design itself. Design Exploration provide ways for automated optimization while developing trust in its results.
- Design Optimization helps engineers answer the following questions:
 - Which product design parameters are the best?
 - How to improve product characteristics?
 - How to decrease effect of parameters variability on overall product behavior?



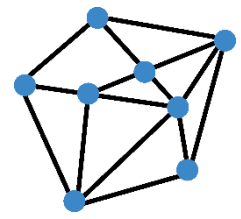
Create model



Define variables
and goals

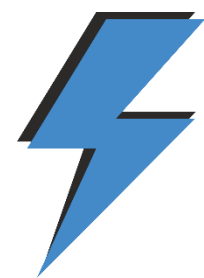


Run optimization



Design Optimization in pSeven

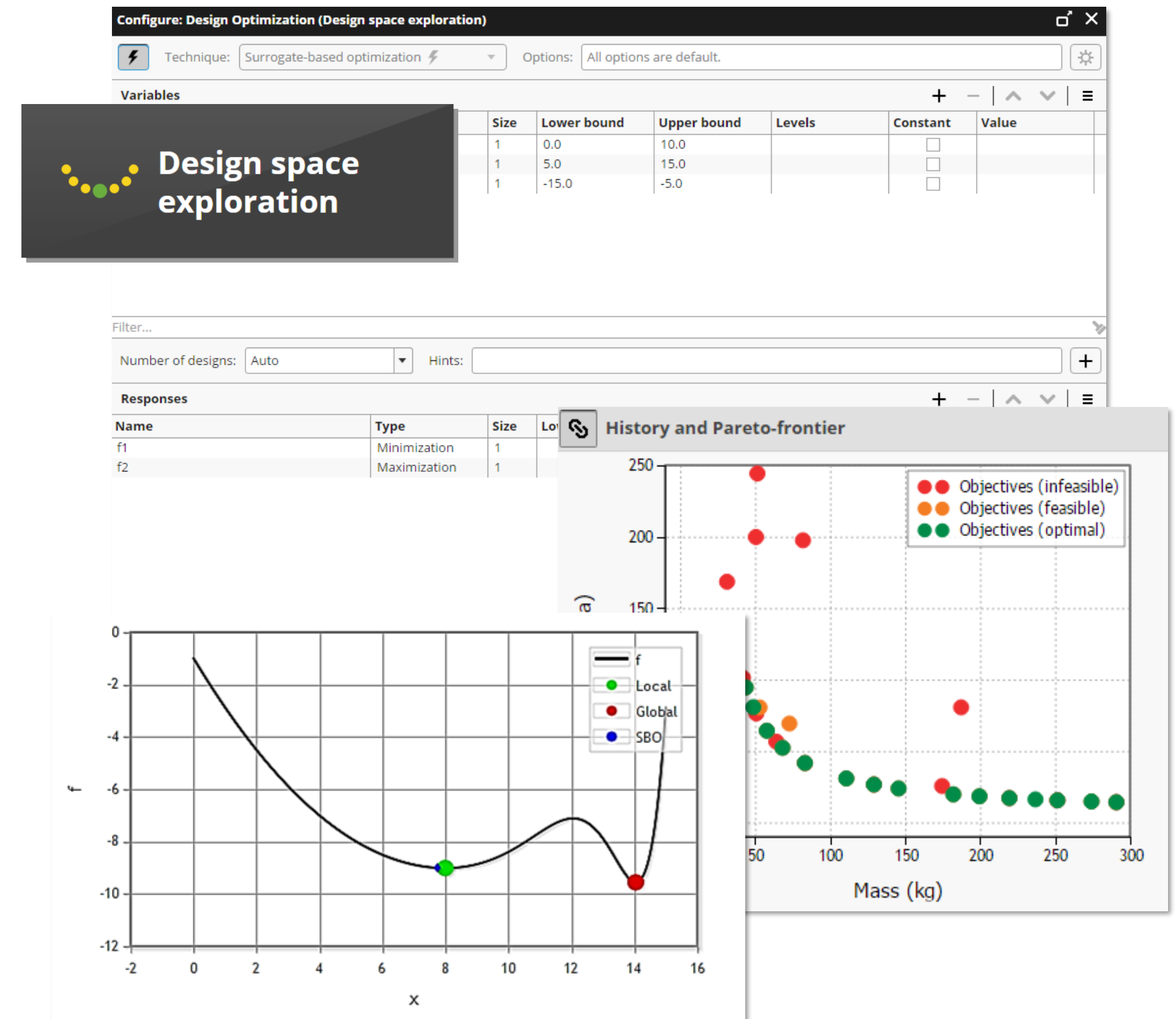
- pSeven provides easy and effective solution for most of industry optimization problems:
 - Single- or multi-objective, robust optimization
 - Large **dimensionality***
 - Long model **evaluation time****
 - **Continuous** and **discrete** input variables
 - **Nonlinear**, **multimodal** or **noisy** objective functions and constraints
 - Presence of **implicit constraints** and domains of **undefined behavior**



SmartSelection chooses the optimization algorithms **automatically** and **adaptively**!

* - Up to 100 design variables for nonlinear time-consuming models

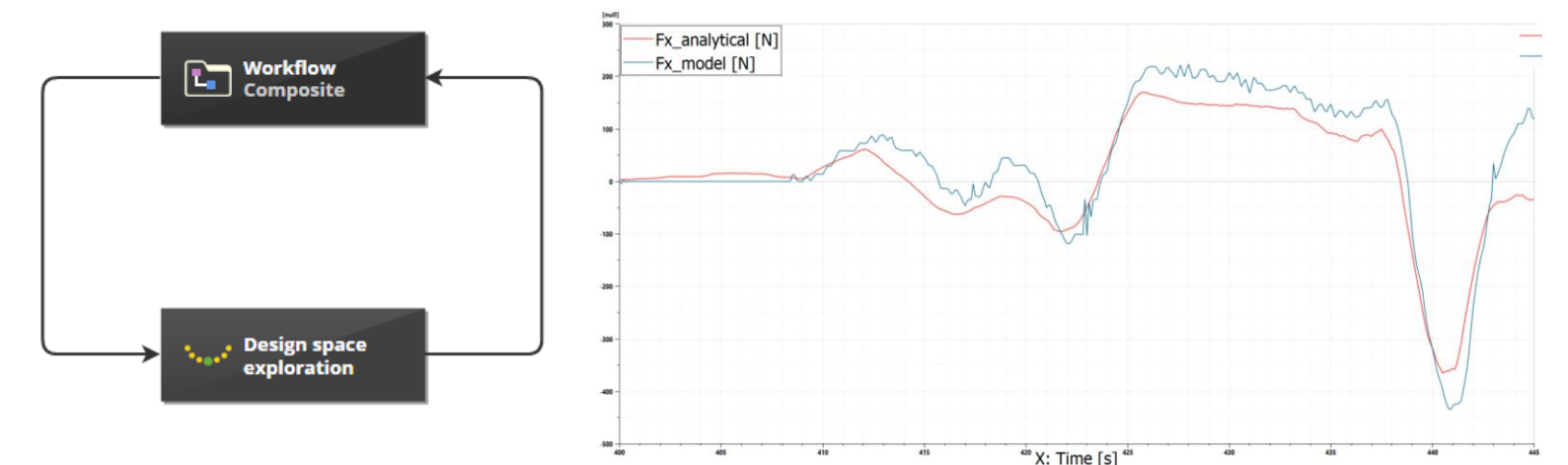
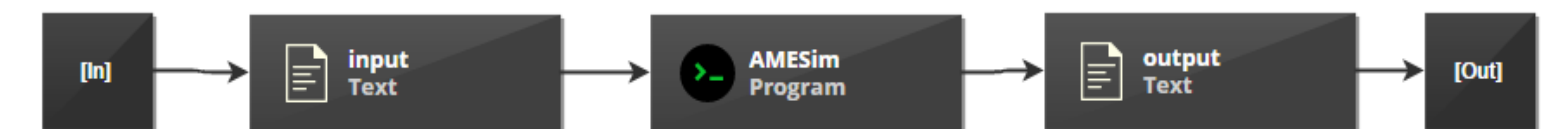
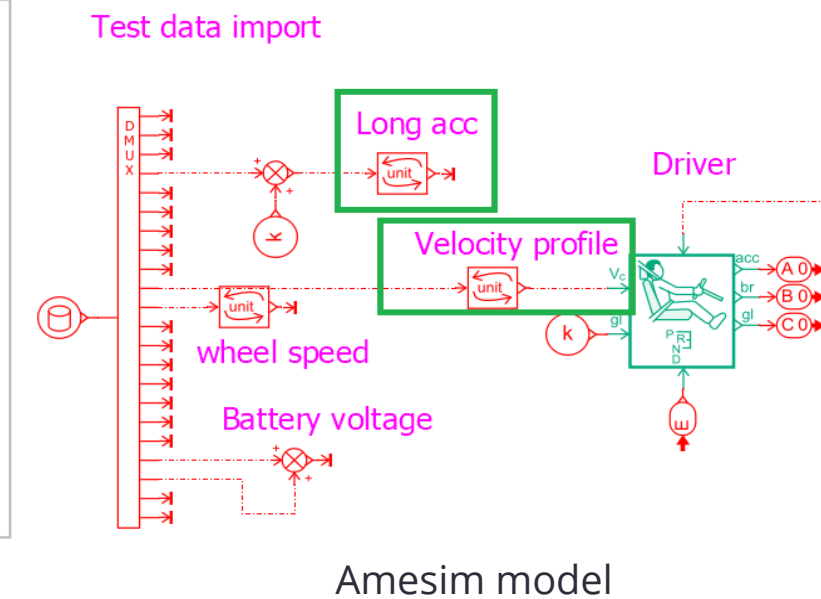
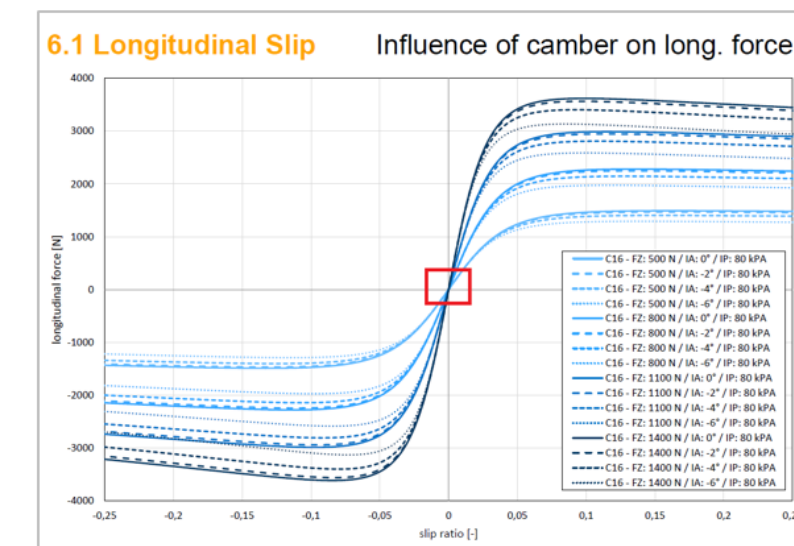
** - For example, any CAE model

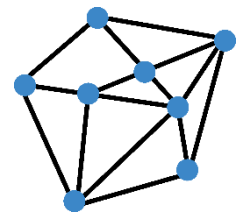




Tire dynamics model identification

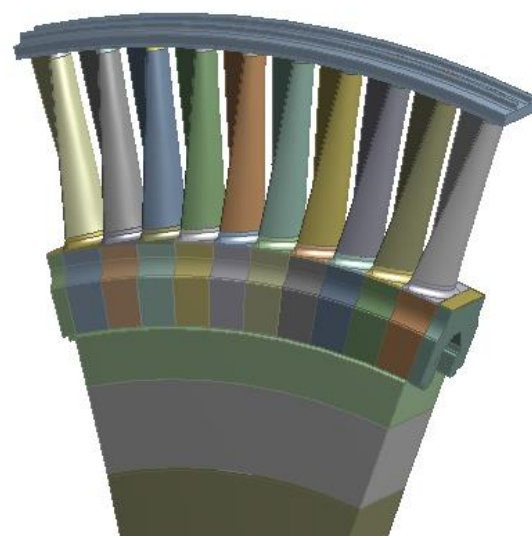
- Objective:
 - Identifying the scale factors for calibration of the tire model of racing bolide.
- Challenges:
 - Mathematical model (Pacejka's "Magic Formula") describing the behavior of tires at given small forces in the contact patch is in a narrow range => it is very difficult to catch the change in force and bind this change to a specific scale factor.
- Solution:
 - Amesim simulation model was integrated into pSeven workflow.
 - Using Gradient-Based Optimization the problem of single-criteria optimization with 6 variables was solved.
- Results:
 - Calibration accuracy **increased by 1.36%** compared to previously used approach.
 - The total identification time for the scale factors was 300 seconds (5 min).





Design of Experiments in pSeven

- Design of Experiments (DoE) is a selection of model input variables (x) at which responses (f) are measured to achieve specific goals:
 - Explore design space using as **small number** of observations as possible
 - Get as much **information** as possible about the model behavior
 - Measure output **sensitivity**, variability and other characteristics
 - Enable reliable **surrogate-based optimization**
 - Generate a training sample for building an accurate **predictive model**

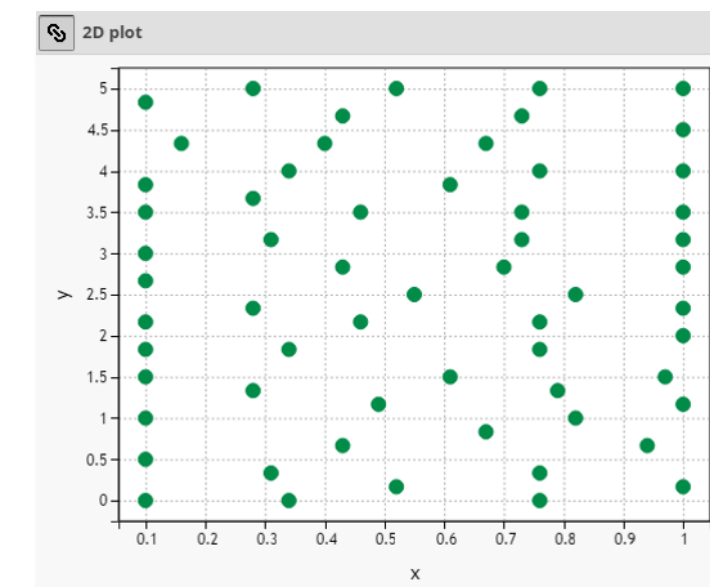


Create model

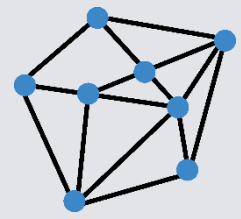


\vec{x}
 \vec{f}

Define variables
and responses

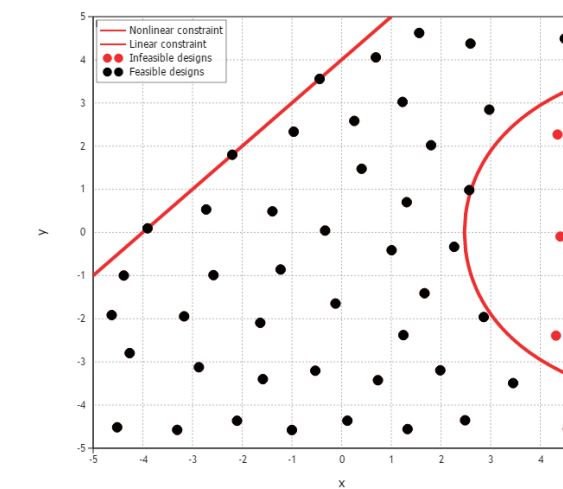


Run a series of model
evaluations

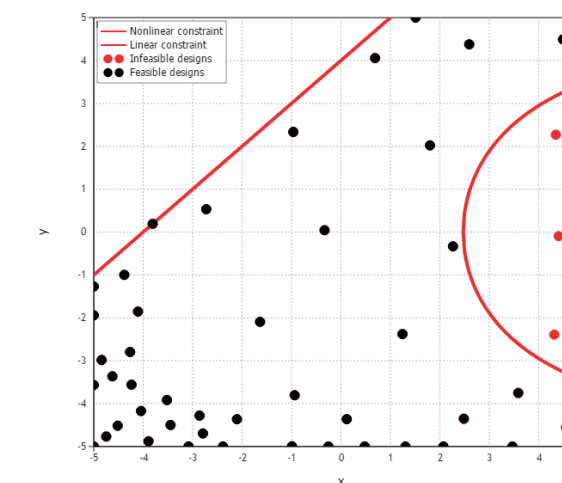


Adaptive design technique for DoE

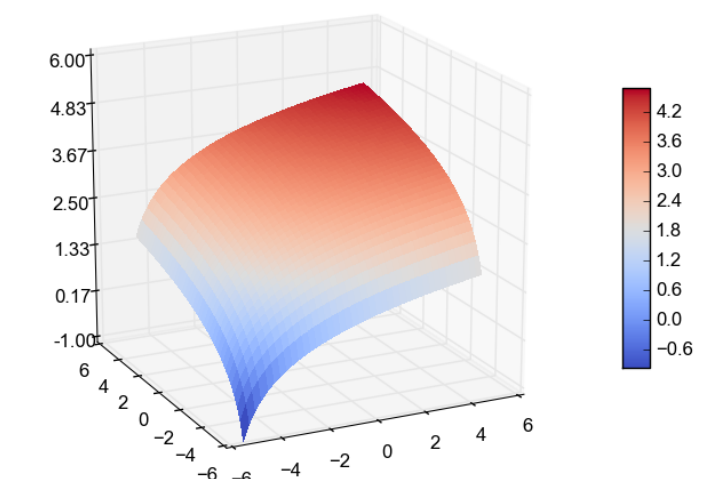
- Adaptive Design technique supports 3 scenarios:
 - Uniform - feasible domain sampling:
 - Setup: variables and bounds, linear and non-linear constraints
 - Result: uniform sample in feasible domain
 - Explore - response surface improvement:
 - Setup: variables and bounds, linear and non-linear constraints, objective function
 - Result: sample in feasible domain for better objective function approximation
 - Contour - search for designs with given objective function value:
 - Setup: variables and bounds, linear and non-linear constraints, objective function and its required value
 - Result: sample in feasible domain with given value of objective function



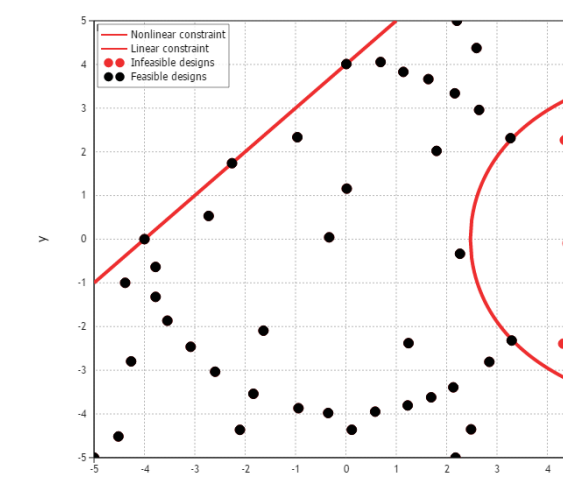
Uniform



Explore



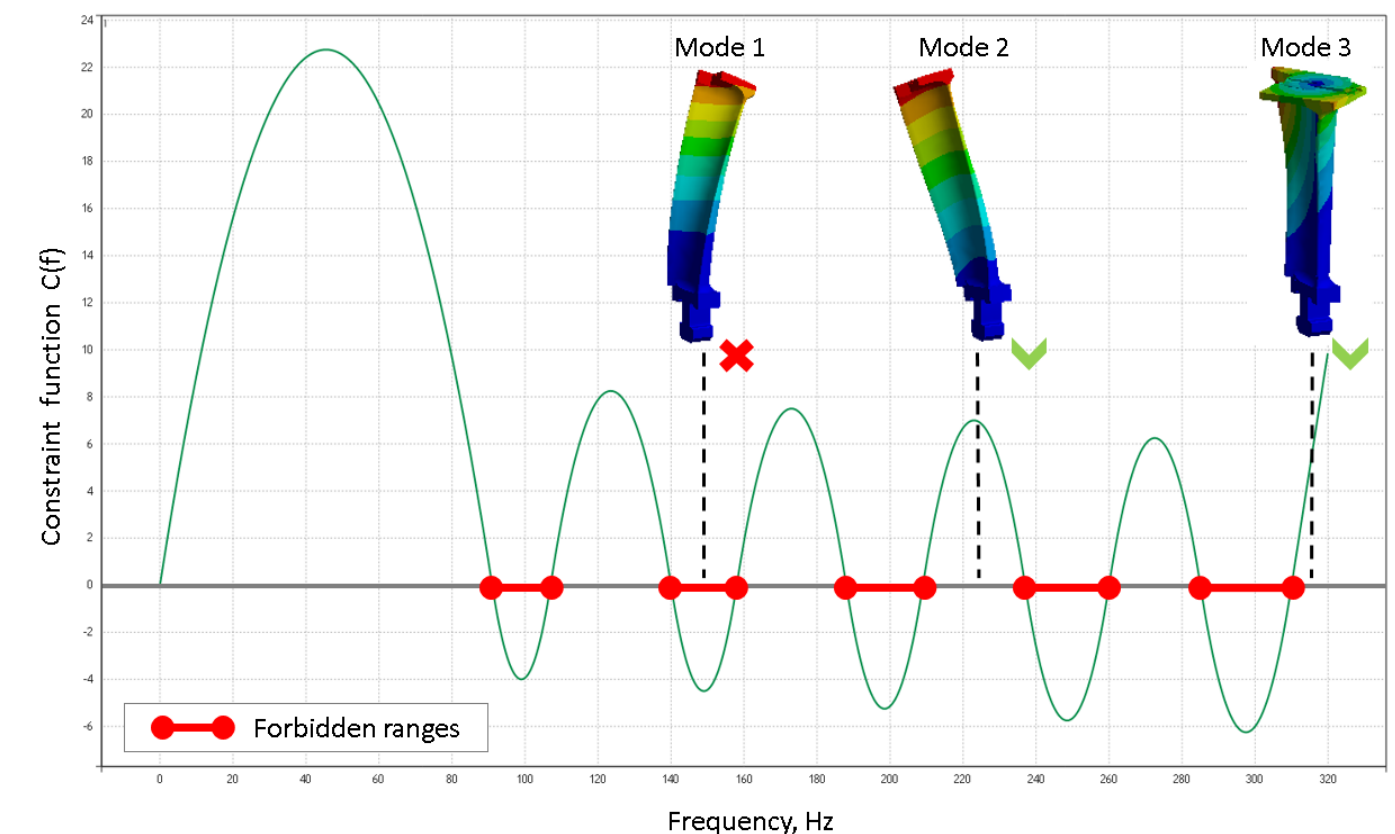
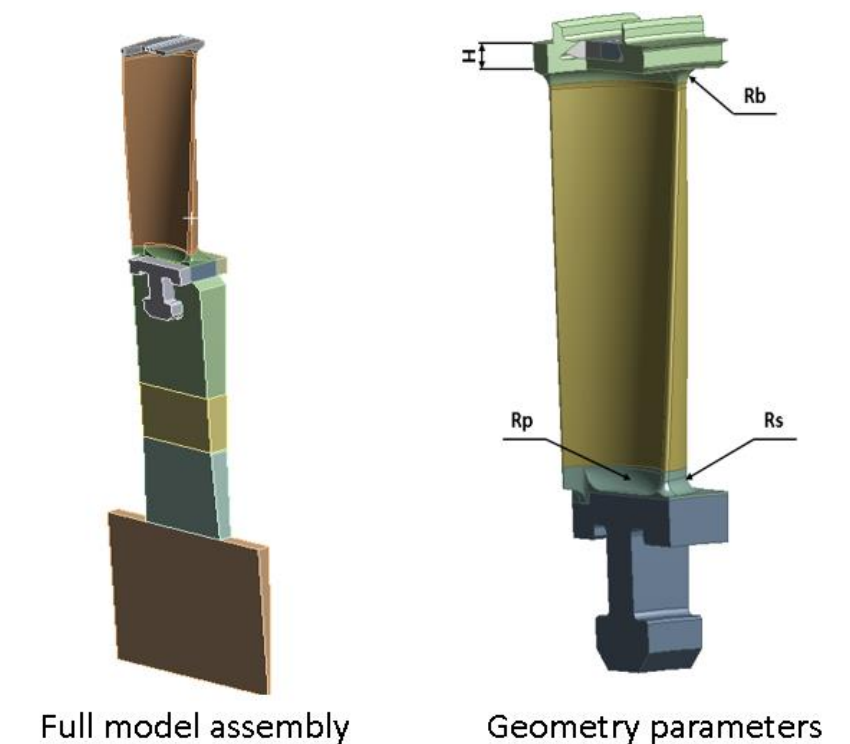
Objective function



Contour

Turbine blades automatic detuning from resonance modes

- Objective:
 - Automate the selection of steam turbine blades geometry parameters.
 - Detune bucket exciting frequency from resonance modes in the operational regimes.
- Challenges:
 - Complex blade geometry with a significant number of elements.
 - No off-the-shelf methodology of frequency and modes evaluation and separation.
- Solution:
 - Meshing and strength analysis performed in Ansys Mechanical.
 - Integration workflow with special scripts to define the logic of computations was created in pSeven.
 - The algorithm of Adaptive Design of Experiments (ADoE) was applied to find the geometry. AdoE allows to generate uniform and non-uniform samples with respect to all constraints, while saving computational budget.
- Results:
 - The module of bucket exciting frequency from resonance modes was developed within the **Integrated Computational Platform (ICP)**, which enables to design turbine blades automatically complying with the number of requirements

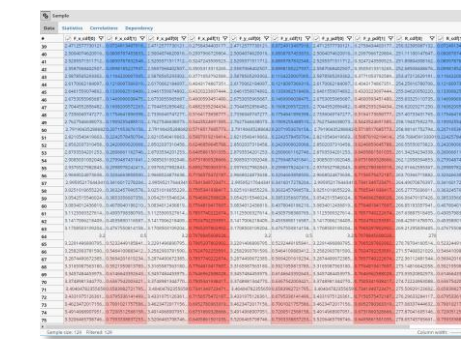




What is a predictive model?

- Predictive model* is a substitution (“black box”) of existing data, analytical model or simulation built with approximation techniques.
- Predictive modeling makes it possible to:
 - **Predict** response function values for new designs
 - **Accelerate** computation of complex simulations by many orders of magnitude
 - Use fast and accurate predictive models in **parametric** and **optimization** studies
 - **Capture** essential knowledge from vast amounts of data
 - Easily and safely **exchange** models between partners preserving IP rights

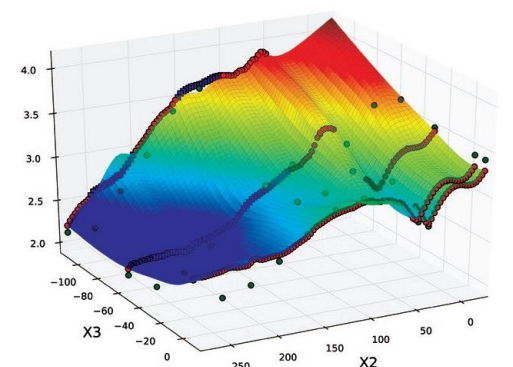
* - Predictive models are also often called regression models, approximation models, response surface models (RSM), surrogate modes, metamodels etc.



Data set

$$f(x)$$

Analytical model



Predictive model

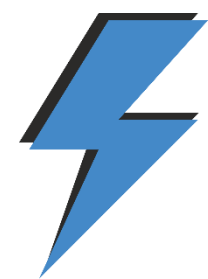


Simulation model

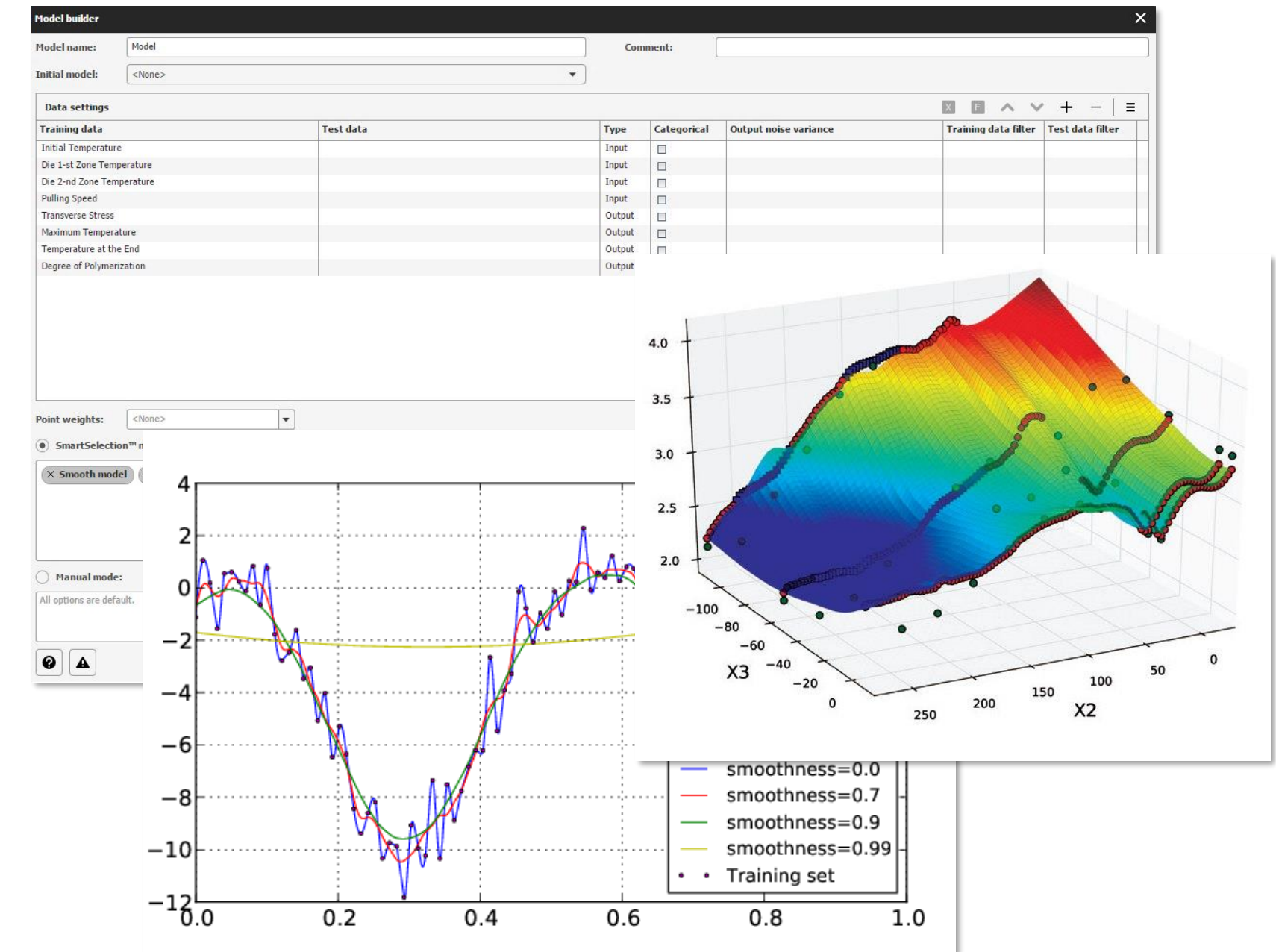


Building predictive models

- pSeven provides unbeatable capabilities and flexibility for building predictive models:
 - Variety of industry-proven approximation techniques
 - Full control of the model building time
 - Accuracy and error estimation
 - Dealing with oscillations and model smoothing
 - Logarithm of outputs and exact fit
 - Handling anisotropic data, discontinuities and inhomogeneous data, multi-fidelity data
 - Updating existing models with new data and combining of the models



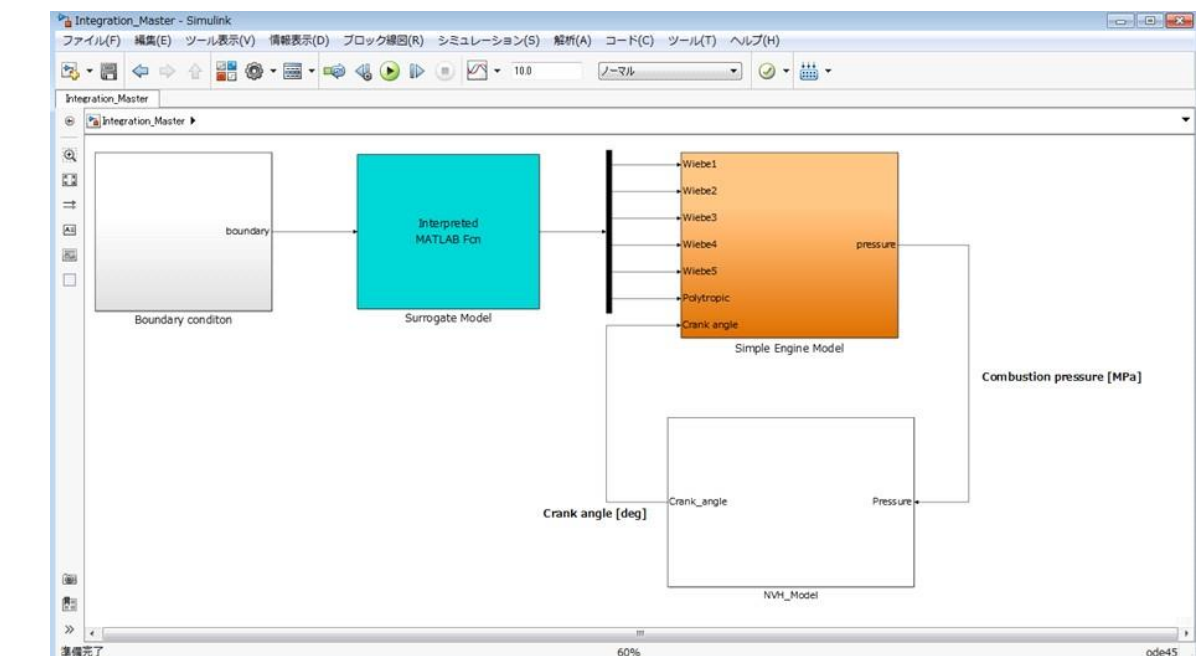
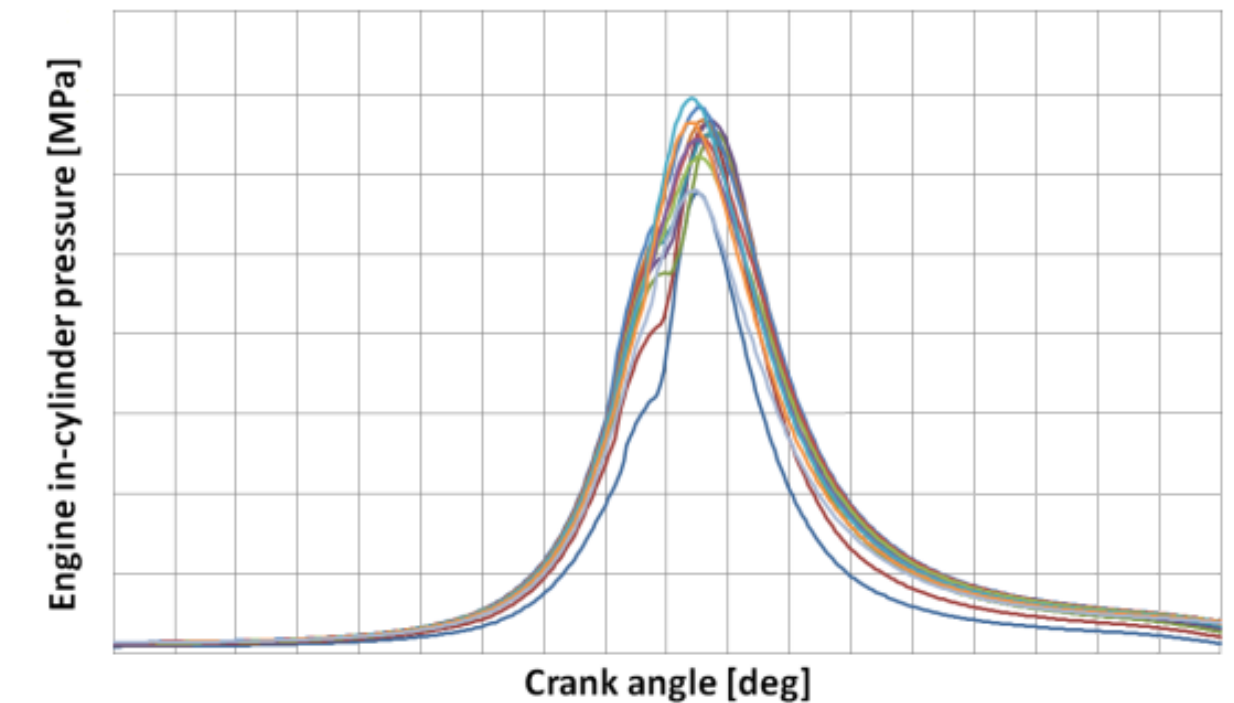
SmartSelection selects the most efficient technique for a given problem and data automatically!





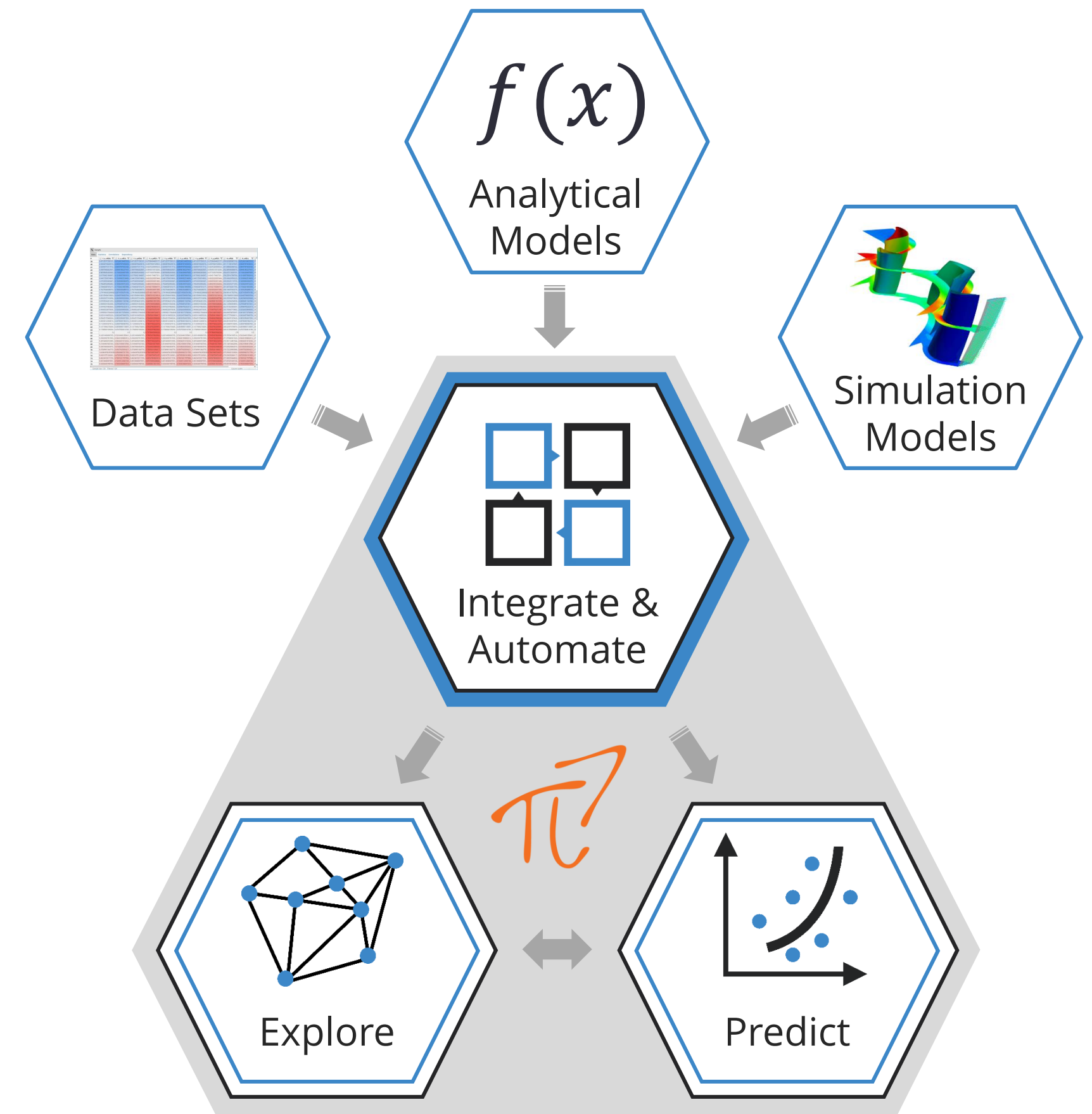
Fitting and predicting of combustion model parameters

- Objective:
 - Accurate engine modeling requires to know combustion model parameters at arbitrary operation regimes:
 - Wiebe function (5 parameters)
 - Specific heat ratio
- Challenges:
 - Fixed number of experimental data available.
 - High accuracy of predictions is required.
- Solution:
 - **1 stage:** Fitting combustion model parameters to existing experimental in-cylinder pressure vs. crank angle curves using optimization of residuals.
 - **2 stage:** Creating approximation model to predict combustion model parameters at an arbitrary regime using known values, like intake and exhaust manifold pressure, fuel consumption, injection timing, RPM etc.
- Results:
 - Fast and accurate approximation model was created that can be used in further 1D engine simulations via export to FMI.



Integrate, Explore & Predict

- pSeven allows to:
 - Capture and **automate** engineering process in the form of a workflow with the aid of **integration** blocks
 - **Explore** your model with tools for **Design Exploration**
 - **Predict** responses for new designs or operational regimes of the product with **Predictive Modeling**



THANK YOU

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