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NORTH AMERICA

**Enhancing the design efficiency of
downhole tools used in energy services
with surrogate models and optimization**

um
2023

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Digital and Automation Team Lead



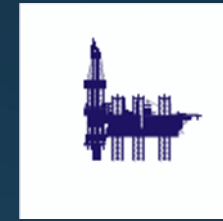


We are a global technology company, driving energy innovation for a balanced planet

From exploration data to subsea intervention



Digital and Integration



Well Construction

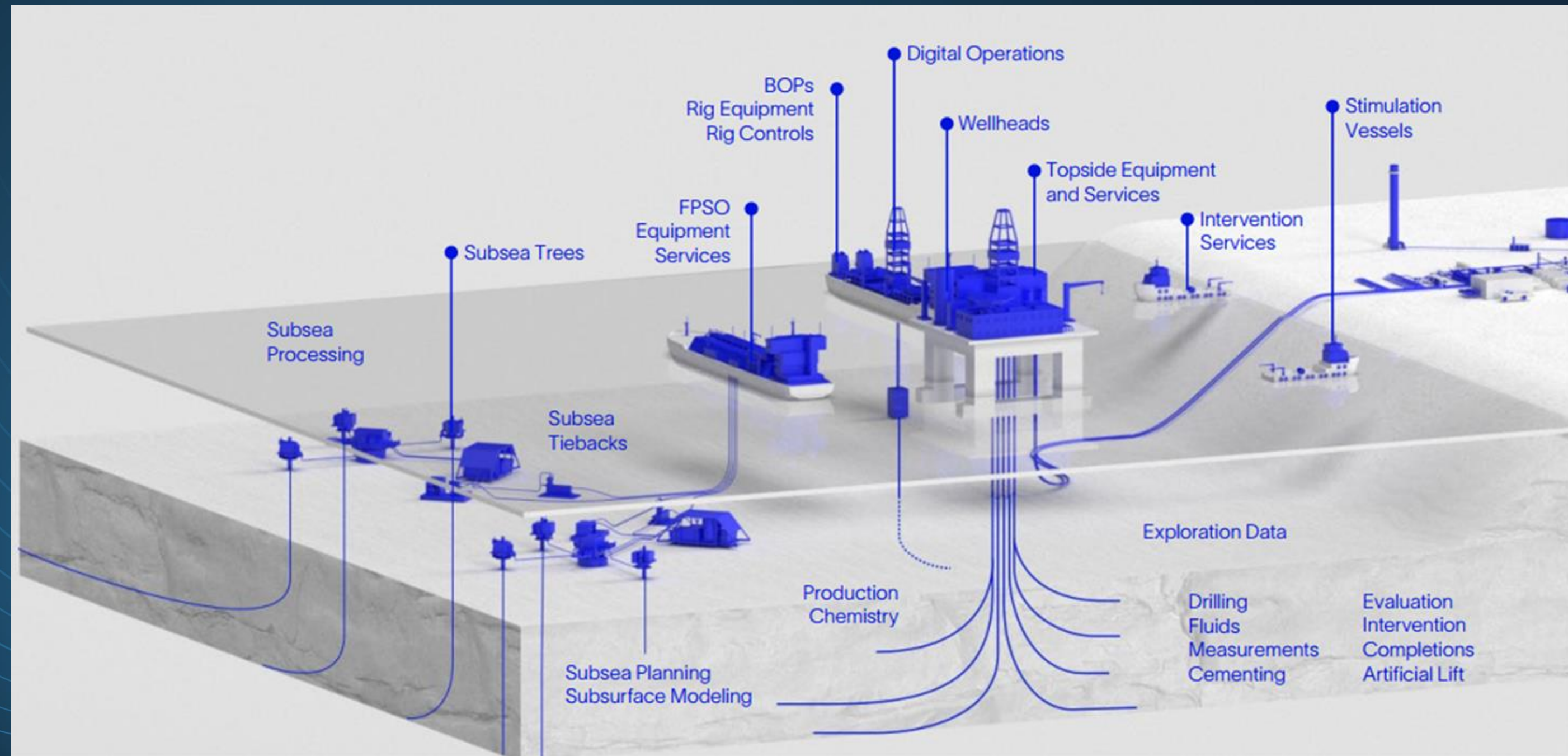


Reservoir Performance



Production Systems

 Technology innovator	 100,000 + People
 170+ Nationalities	 120 + Countries
 65 Technology Centers	 ~100 years of heritage
 Product & Services	 ~\$28 bn Revenue in 2022



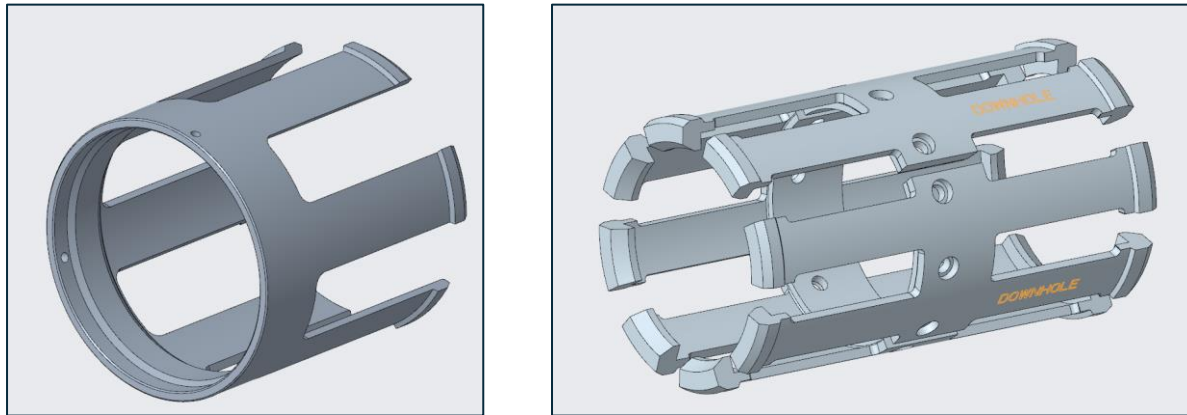


- Background
- Traditional Approach
- Surrogate Modelling (RSM)
- Optimization
- Democratization

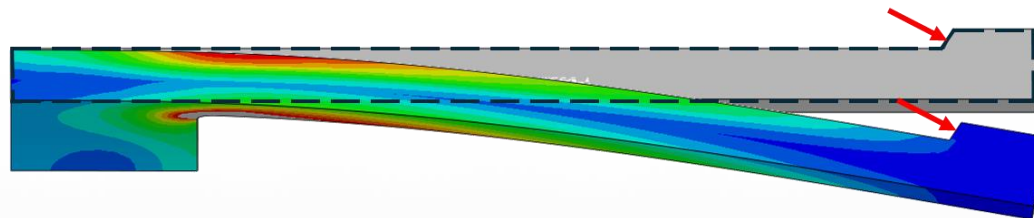


Collet device in energy services tools

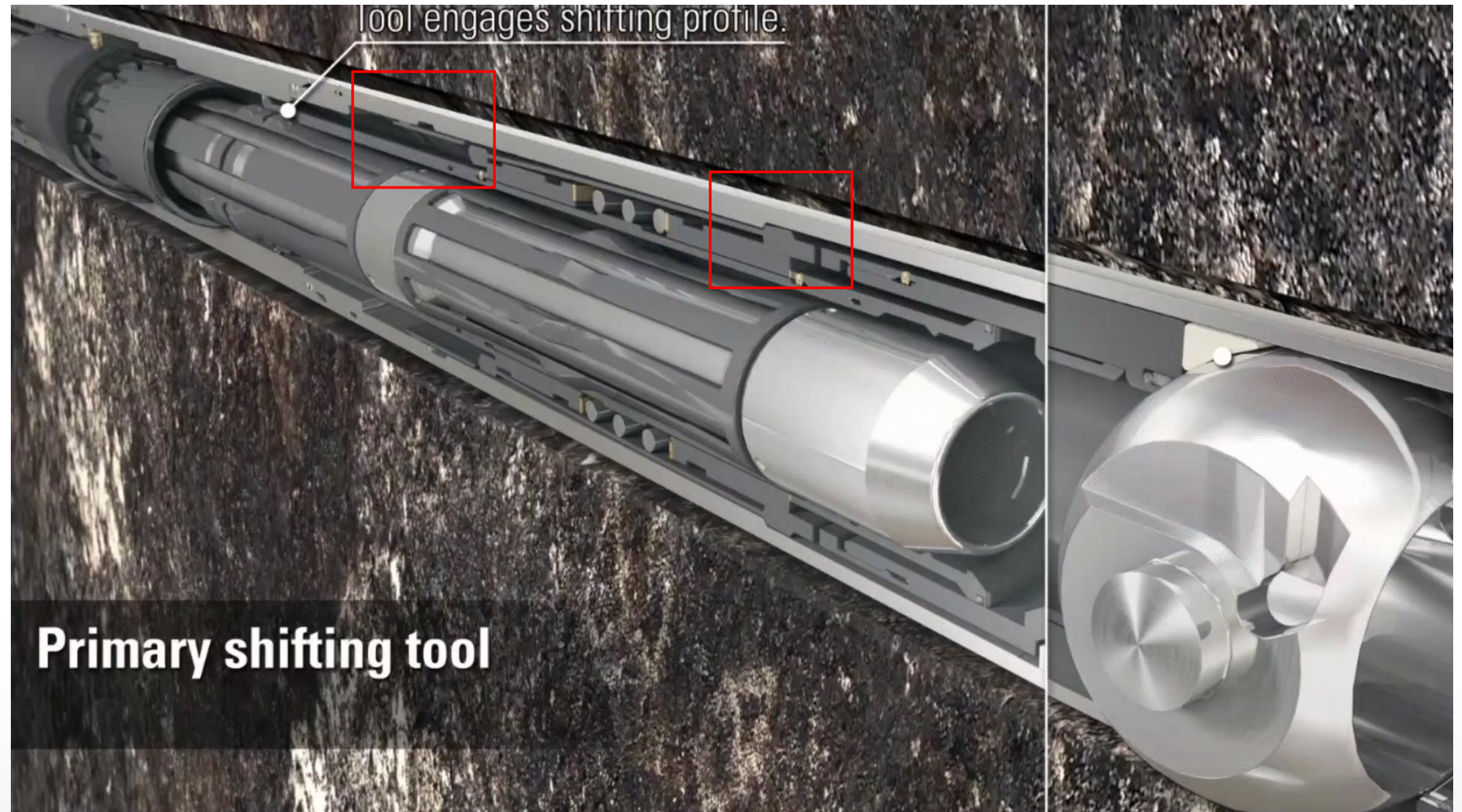
- Collet
 - mechanical locking device
 - retain position until specified force is applied



- Unlatches from a profile (force deflects finger)
- Force-Deflection relationship is critical for design!



Formation Isolation Valve has collet actuations.



Primary shifting tool

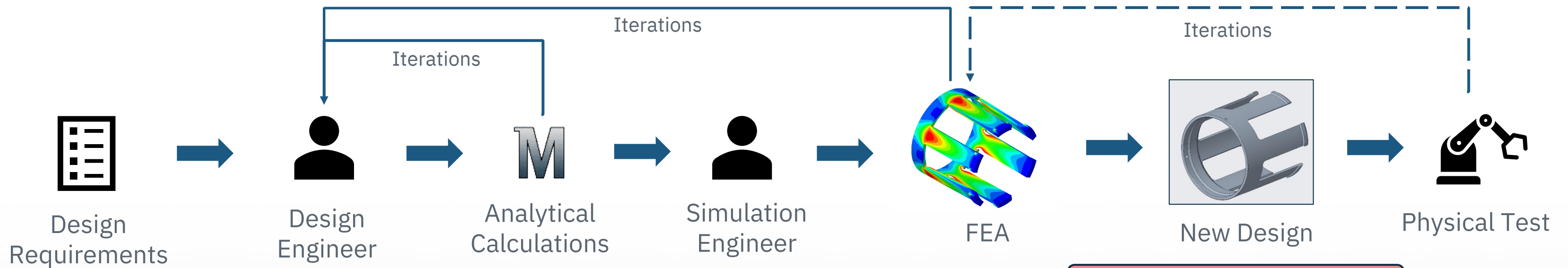
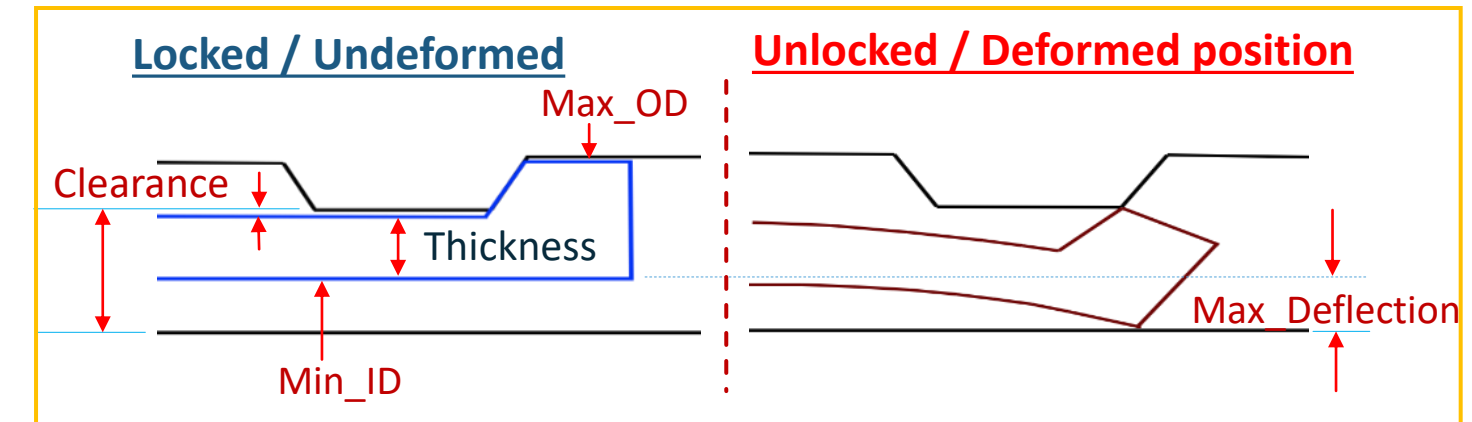
Challenges with Traditional Method

Design Variables:

- Number of fingers
- Thickness of fingers
- Width of fingers
- Length of fingers

Design Constraints:

- Force +/- tolerance
- Geometric space for deflection
- Max stress



Low-fidelity
 (Error 15% - 40%
 compared to FEA)

Non-optimized Design

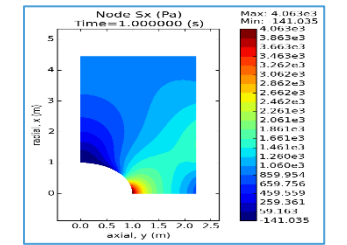
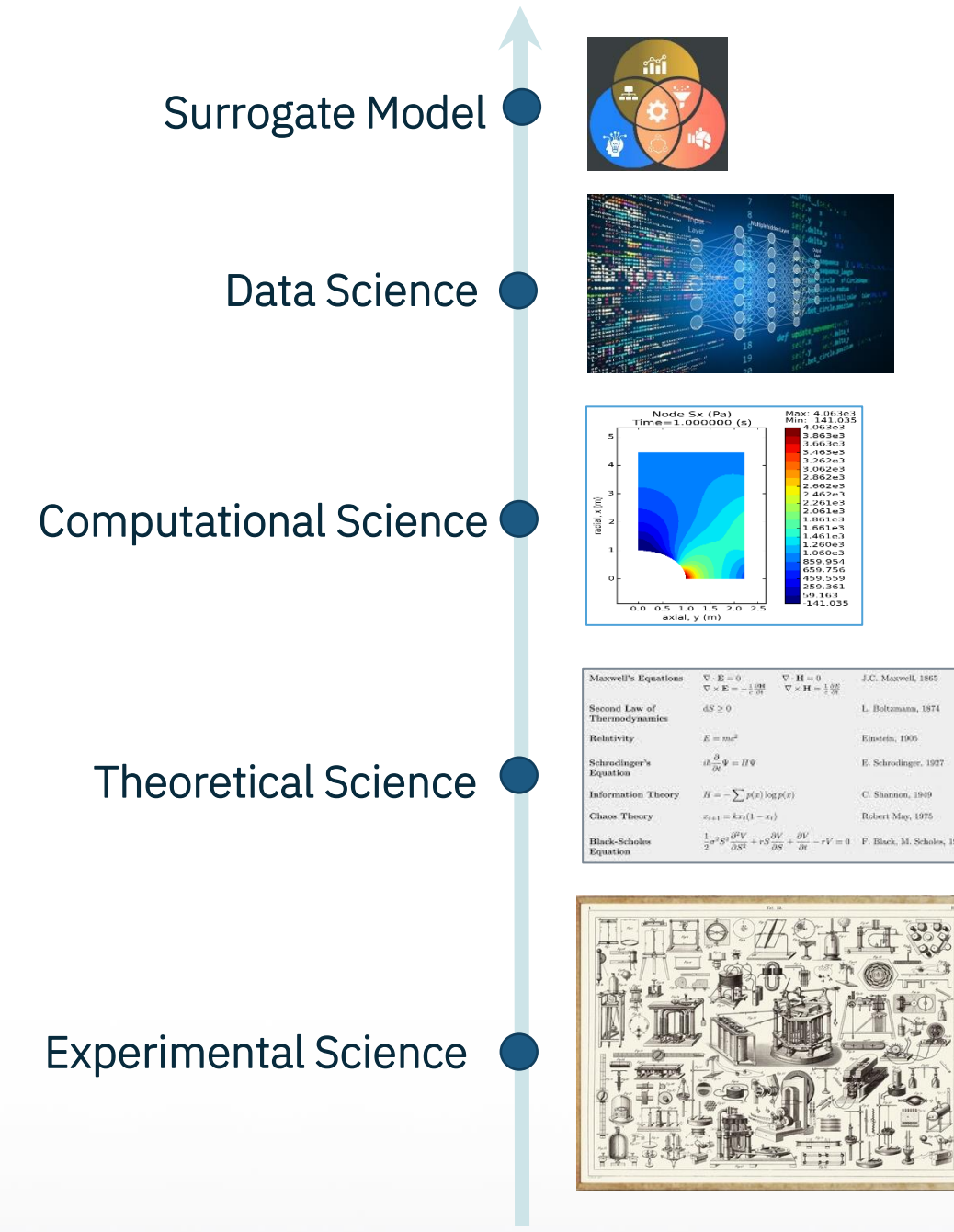
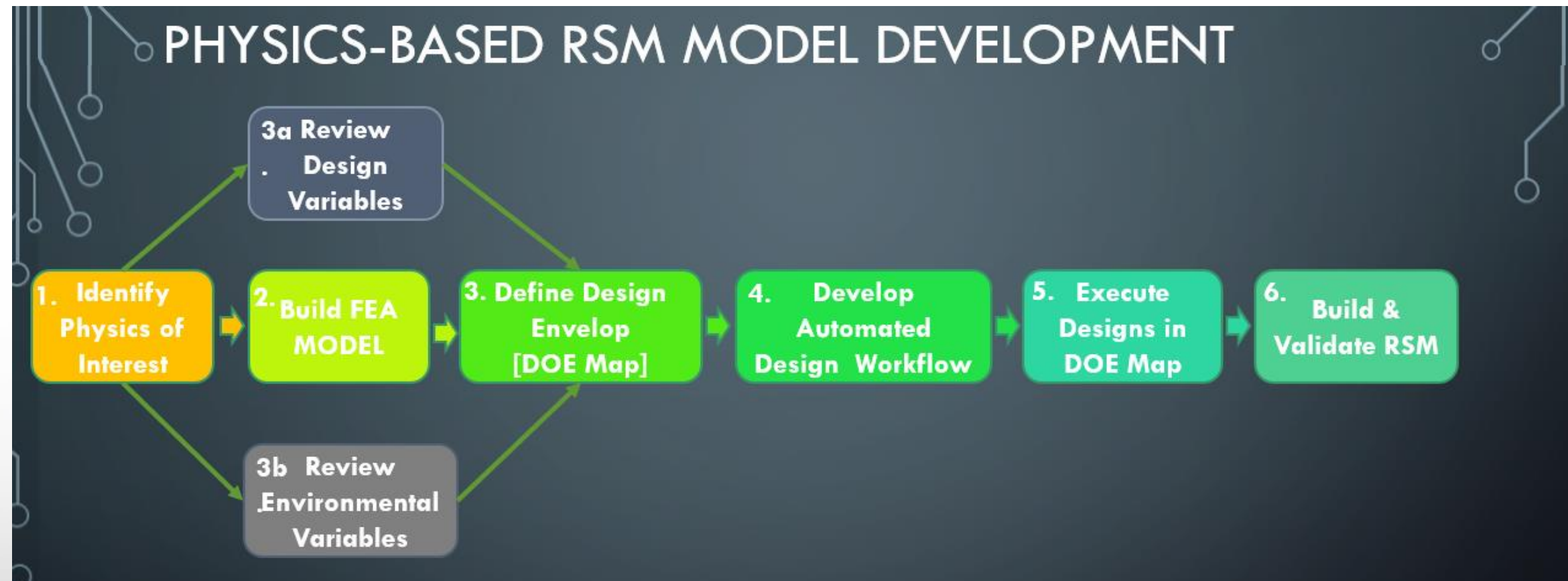
Long turn-around time



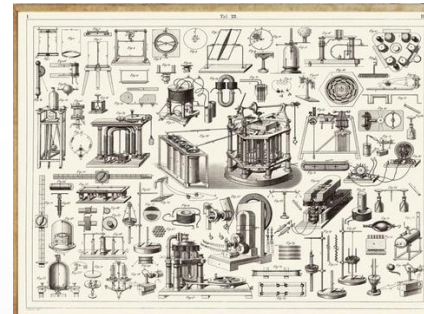


Surrogate model

- A **mathematical approximation** of a physical phenomenon.
- Generated from output data of high-fidelity simulation models.
- Uses machine learning.
- Enhance with operational data, experiments, and simulations.
- **“Model of a model”** that iterates faster than a complex physical system.
- **Accelerates optimization** & explores system behavior efficiently.
- Other nomenclature: proxy, metamodel, emulator, response surface model, or black box.

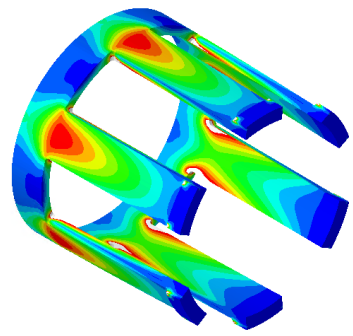


Maxwell's Equations	$\nabla \cdot E = \rho$ $\nabla \times E = -\frac{\partial B}{\partial t}$	$\nabla \cdot H = 0$ $\nabla \times H = \frac{\partial E}{\partial t} + J$	J.C. Maxwell, 1865
Second Law of Thermodynamics	$\Delta S \geq 0$		L. Boltzmann, 1874
Relativity	$E = mc^2$		Einstein, 1905
Schrodinger's Equation	$i\hbar \frac{\partial \psi}{\partial t} = H\psi$		E. Schrodinger, 1927
Information Theory	$H = -\sum p(x) \log p(x)$		C. Shannon, 1949
Chaos Theory	$x_{n+1} = kx_n(1-x_n)$		Robert May, 1975
Black-Scholes Equation	$\frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS \frac{\partial V}{\partial S} - rV = 0$		F. Black, M. Scholes, 1979

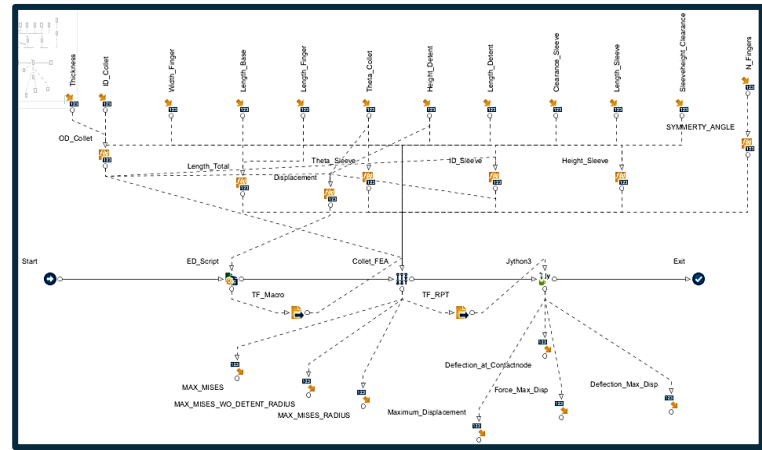


Progression of Engineering Science

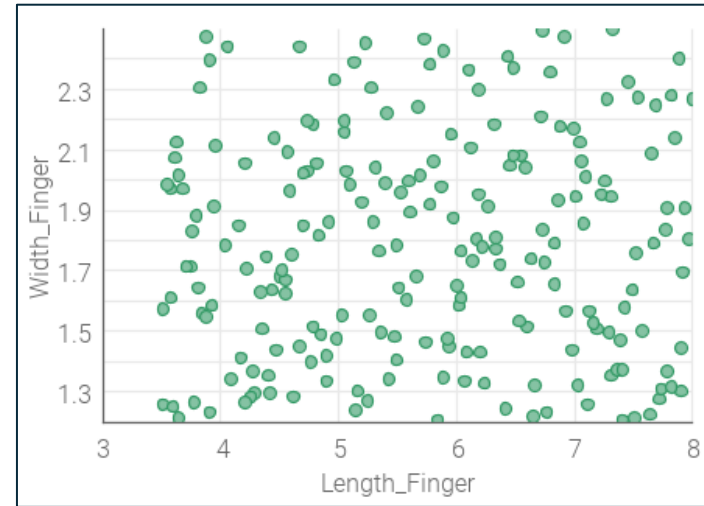




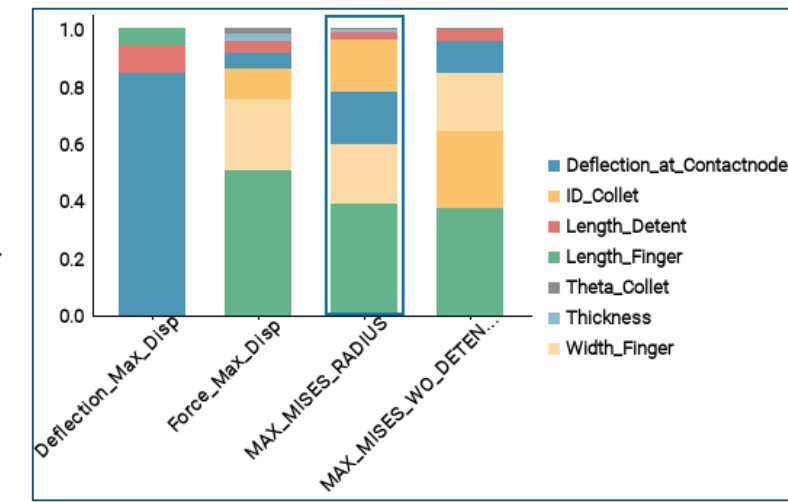
Parametric FEA Model



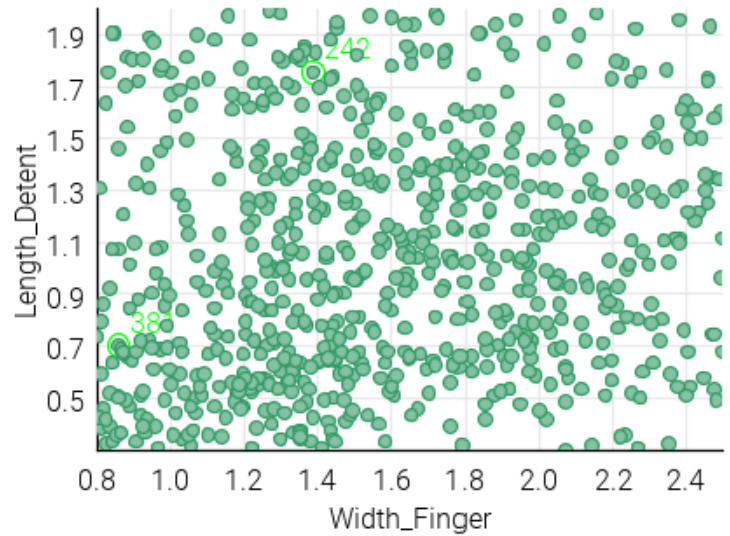
Automated FEA Workflow
 (15 – 20 mins run-time)



Latin Hypercube DOE
 (~200 Feasible Runs)

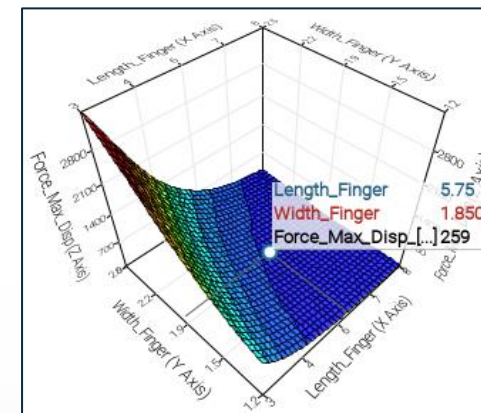


Sensitivity Analysis

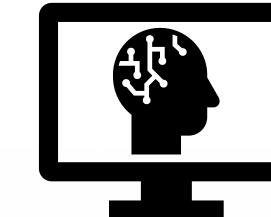


Final Dataset
 (~ 600 Feasible Runs)

**Iterations terminates when
 relative mean error
 between RSM and FEA
 outputs < 2%**



Adaptive RSM
 for each iteration



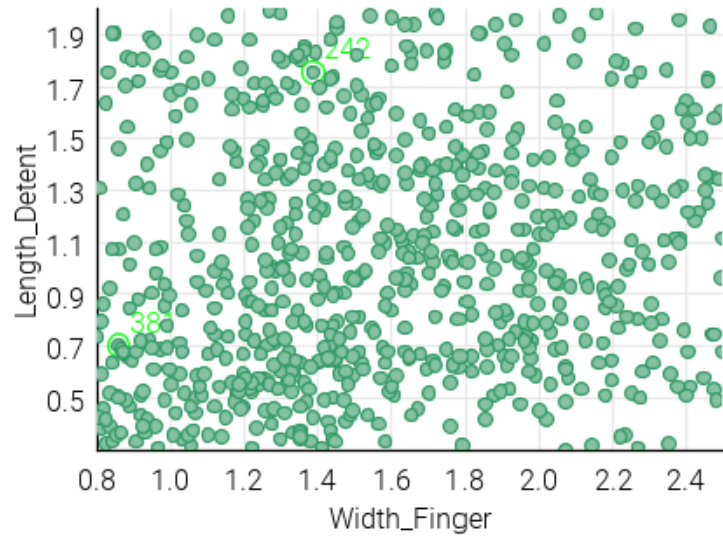
Adaptive Space Filler
 Exploration Algorithm

Parameters with >
 95% main effect





RSM Modelling



Dataset (FEA)

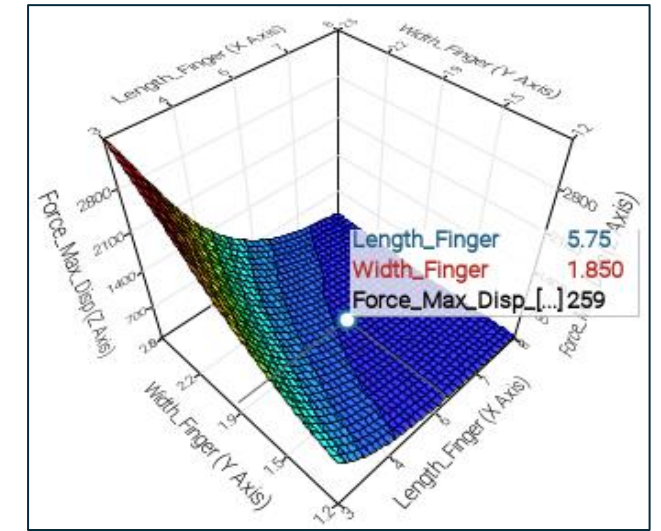
**80%
Training**

**20%
Validation**

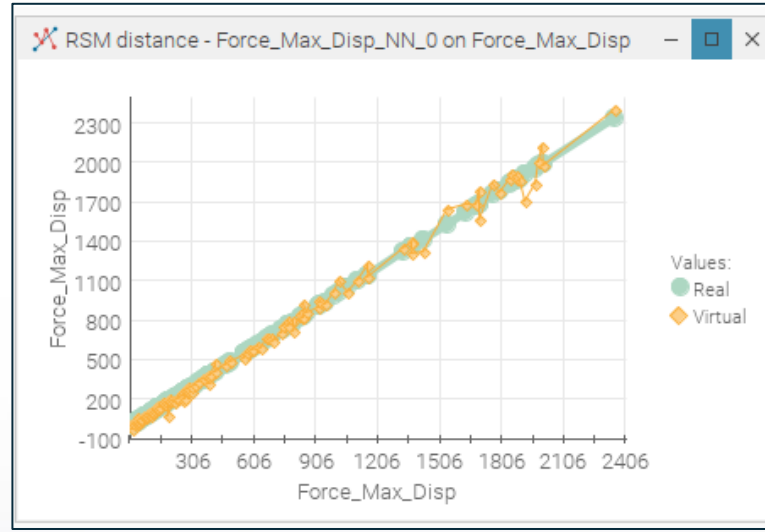
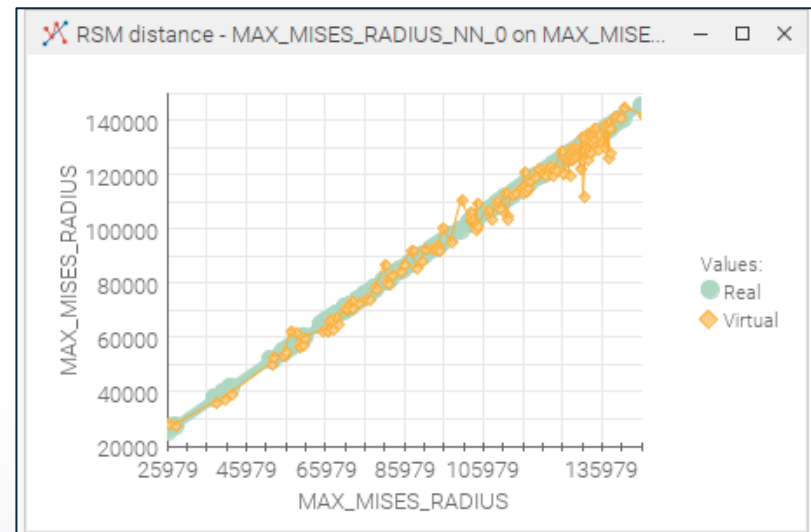


Train and Built
RSM

- Gaussian Processes
- Kriging
- Radial Basis Function
- Neural Networks
- Automatic Machine Learning
- Polynomial SVD



RSMs for force and stress prediction



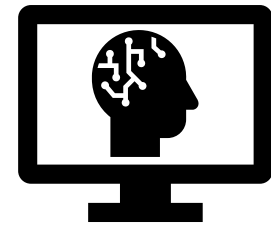
Output	Name	Mean absolute error	Mean relative error	Mean normalized error	R-squared	AIC
Force_Max_Displ	Force_Max_Displ_GP_1	7.33E0	1.42E-2	3.84E-3	9.96E-1	1.03E3
Force_Max_Displ	Force_Max_Displ_H2O_AML_1	1.20E2	3.48E-1	6.28E-2	7.76E-1	5.65E2
Force_Max_Displ	Force_Max_Displ_KR_1	5.70E1	2.09E-1	2.98E-2	8.05E-1	1.22E3
Force_Max_Displ	Force_Max_Displ_NN_1	3.71E0	1.36E-2	1.94E-3	1.00E0	5.76E2
Force_Max_Displ	Force_Max_Displ_RBF_1	2.07E1	6.57E-2	1.08E-2	9.69E-1	1.12E3
Force_Max_Displ	Force_Max_Displ_SS-ANOVA_1	1.18E2	5.54E-1	6.20E-2	8.44E-1	8.18E2
Force_Max_Displ	Force_Max_Displ_STEP_1	1.31E2	6.83E-1	6.87E-2	8.36E-1	5.94E2

RSM Performance Comparison

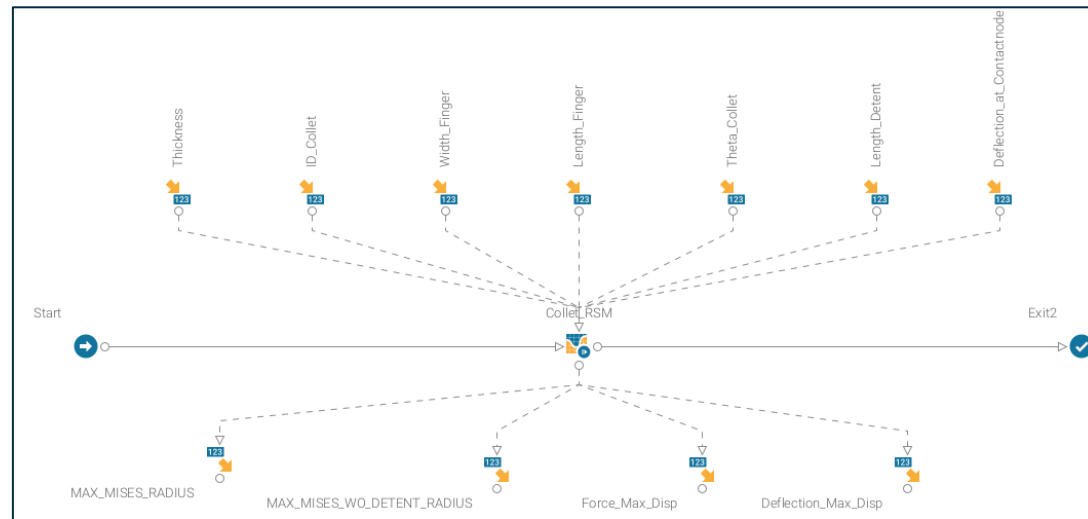
RSM predicts force with mean error of <2% and stress <0.6% in comparison to FEA prediction



RSM Based Design Optimization

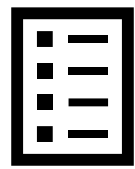


RSM Model

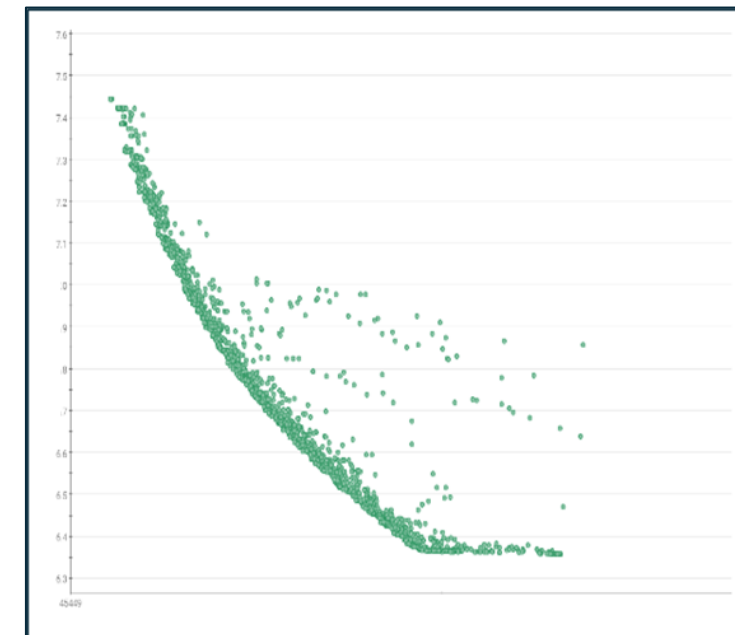


RSM Based Design Optimization
 Workflow

FAST Optimization Algorithm



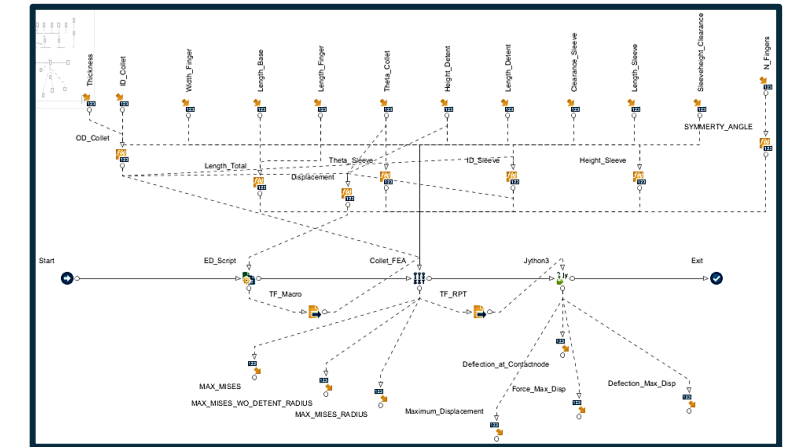
New Design
 Requirement



Length_Finger

Stress

Pareto Frontier

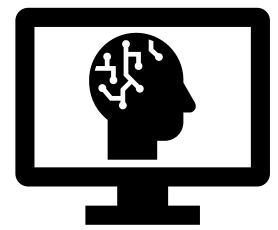


Verification of Optimized
 Design using Automated FEA





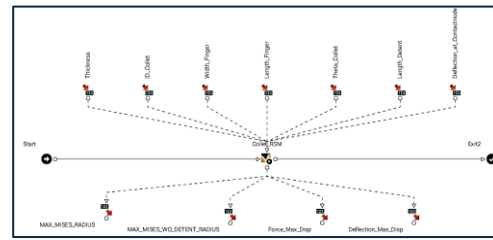
Democratization



RSM Model



modeFrontier RSM Workflow

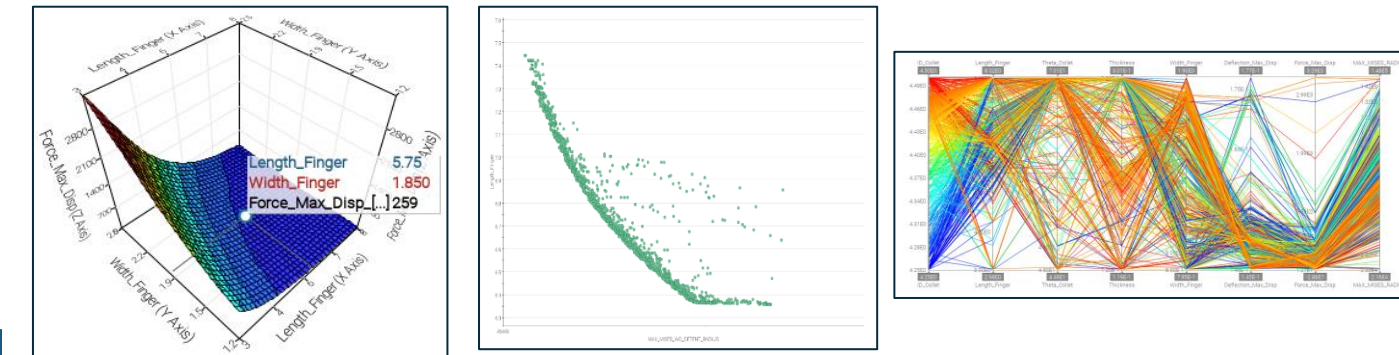


Length_Base	Length_Detent	Length_Finger/N_Fingers	Theta_Collet	Thickness	Width_Finger	Height_Detent
1.15	0.45	4.25	5	0.26	1.85	
						0.08
						0.084
						0.088
						0.092
						0.096
						0.1
4	0.061967676	0.063685152	0.06597727	0.068937672	0.072603472	0.076913
4.2	0.061779172	0.063429586	0.065640288	0.068509302	0.072083616	0.076317
4.4	0.061598342	0.063183671	0.065314695	0.068093192	0.071575265	0.075729
4.6	0.061424934	0.062947152	0.065000296	0.067689303	0.071078637	0.07515
4.8	0.061258896	0.062719768	0.064696884	0.067297573	0.070593908	0.074581
5	0.061099381	0.06250126	0.064404239	0.06691791	0.070121221	0.074022
5.2	0.060946746	0.062291367	0.064122135	0.066550204	0.069660681	0.073473
5.4	0.060800553	0.062089828	0.063850333	0.066194323	0.069212362	0.072935
5.6	0.060660567	0.061896383	0.063588591	0.065850113	0.068776303	0.072408
5.8	0.060526561	0.061710774	0.063336658	0.065517405	0.068352513	0.071892
6	0.06039831	0.061532745	0.063094281	0.065196015	0.067940972	0.071388

RSM exported as FMU to Excel

name	type	value	lower bound	upper bound	step	seed
Deflection_at_Contactnode	RF	0.05	0.05	0.25		
Thickness	RF	0.26	0.12	0.4		
Length_Finger	RF	5	3	9		
Length_Detent	RF	0.45	0.2	2		
Theta_Collet	RF	45	45	75		
ID_Collet	RF	3	3	6		
Width_Finger	RF	0.26	0.2	2.2		

Volta Deployment



VOLTA Adviser Dashboard for expert users

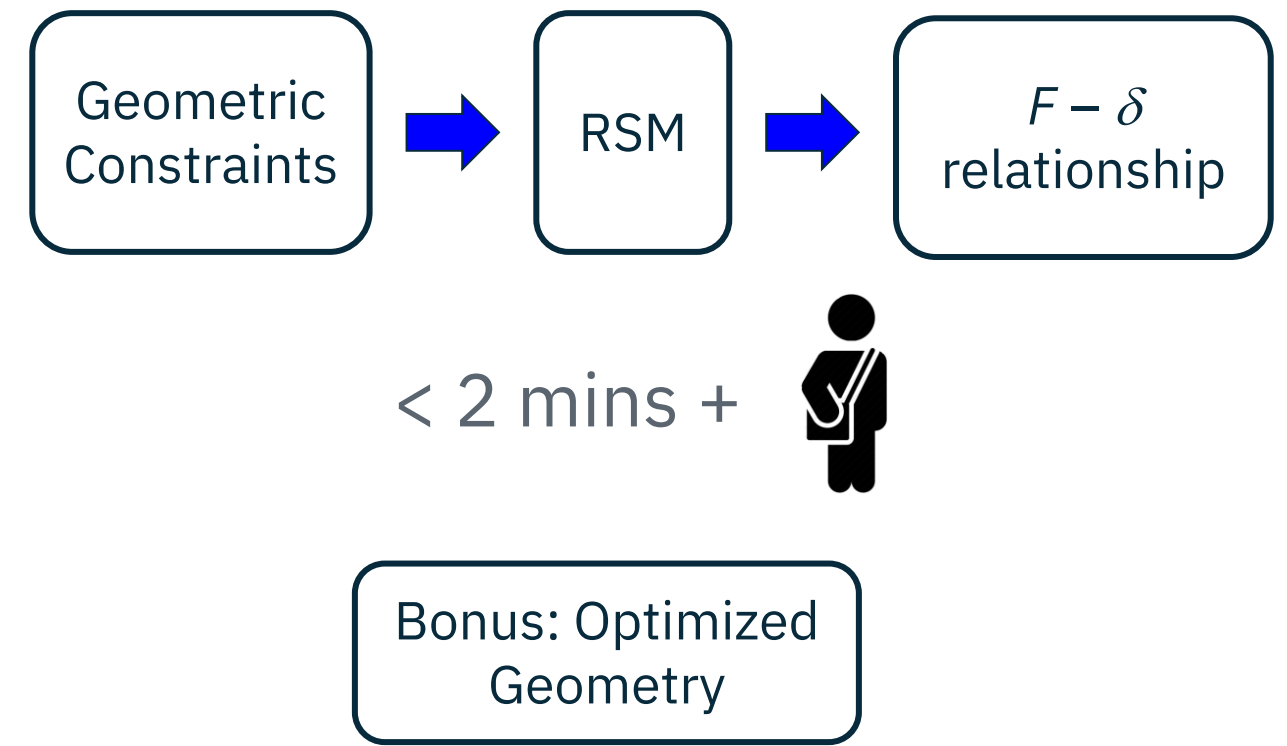
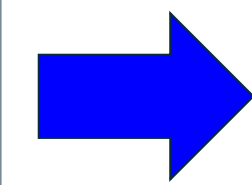
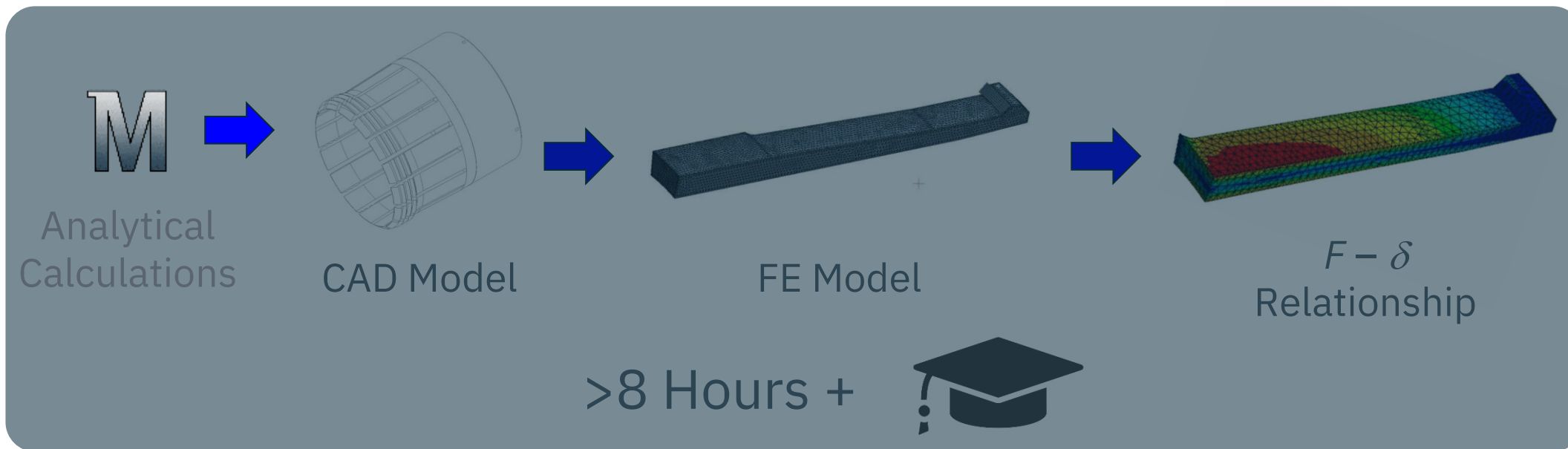


RunBox for non-expert users





Conclusions





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Thank you!

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