On the role of Process Integration and Design Optimization in ECO Electric Motor Design; a proposition

Nick Tzannetakis
Noesis Solutions

Abstract :
Process Integration and Design Optimization are becoming fundamental innovation drivers in the design of products. The methodologies allow for a streamlined, repeatable, design process that removes the breaks in the several design stages, while enabling a function and target driven design where the desired product function is driving the design through optimization. The concepts above will be illustrated in the advanced motor design by uniting Optimus, a commercial software offering that fully covers the functions of Process Integration and Design Optimization and JMAG using a Direct-Interface function though a comprehensive case study.


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On the role of Process Integration and Design Optimization in ECO Electric Motor Design; a proposition
Nick Tzannetakis
Chief Technical Officer
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Thank You
For providing the opportunity to present
Thank you for your attention
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Agenda and Topics

- Process Integration and Design Optimization – What is it?
- Integration with JMAG
- An Example and the Value

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Company Introduction

- The NEW noesis
- A wholly owned CYBERNET Company
- **Mission: Committed** to Provide the Industry with **P**rocess **I**ntegration and **D**esign **O**ptimization Solutions
- **Vision: Enable** the Industry to **Design for real**

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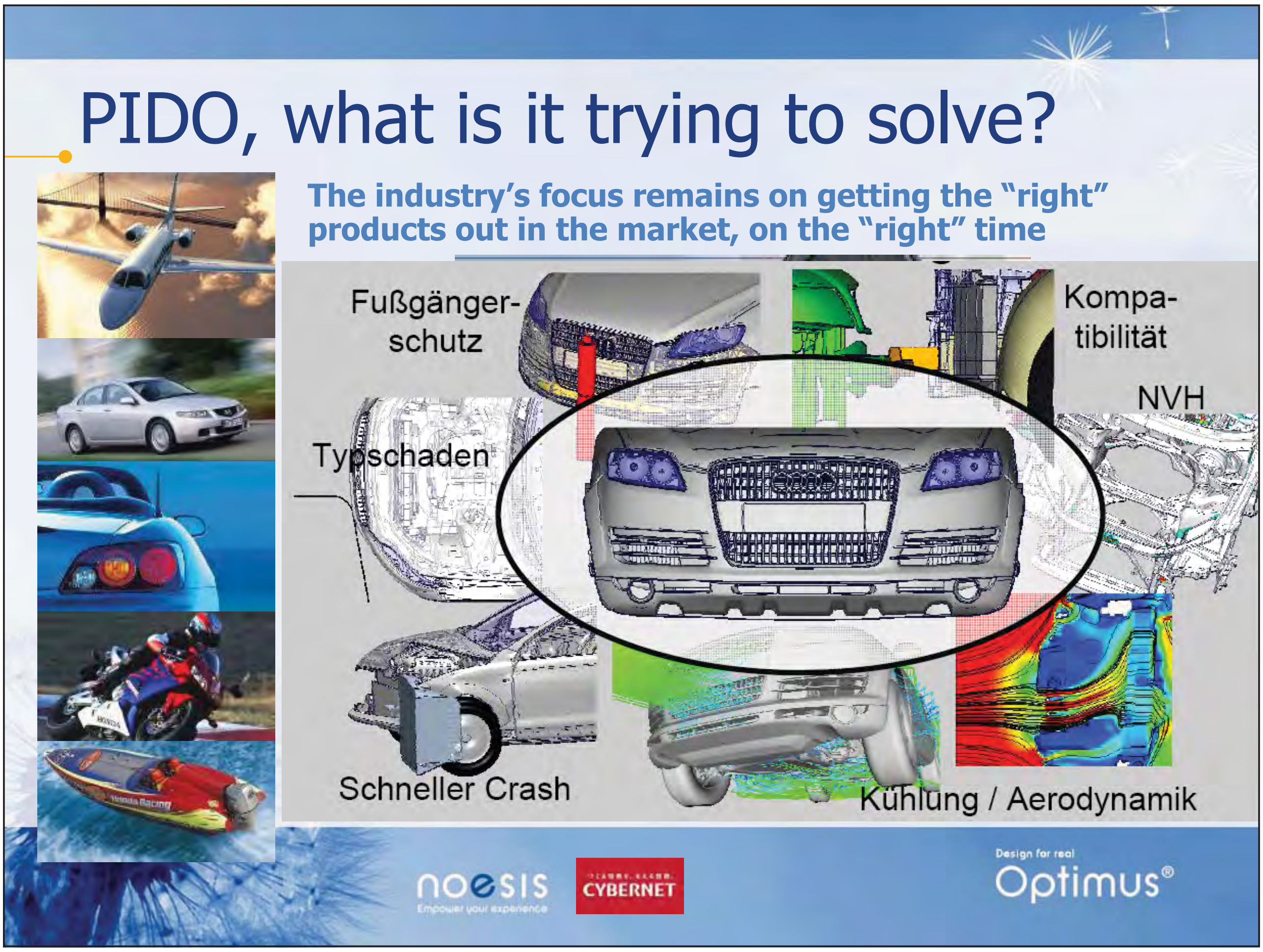
PIDO, what is it trying to solve?
The industry's focus remains on getting the "right" products out in the market, on the "right" time
Fußgänger-schutz
Kompa-tibilität
NVH
Typschaden
Schneller Crash
Kühlung / Aerodynamik
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The Main Elements of the Solution

- The Simulation Capability – Enabler #0
- The Process Integration and Design Optimization
  – Enabler #1 - #6

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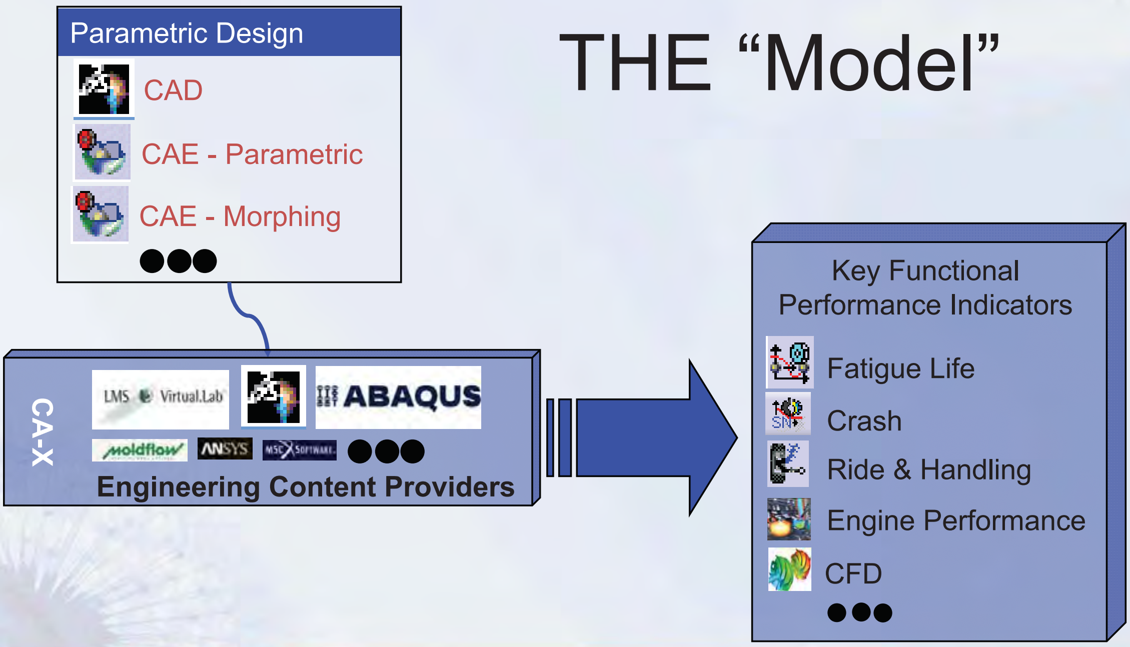
ENABLER #0 – SIMULATION [CAE]



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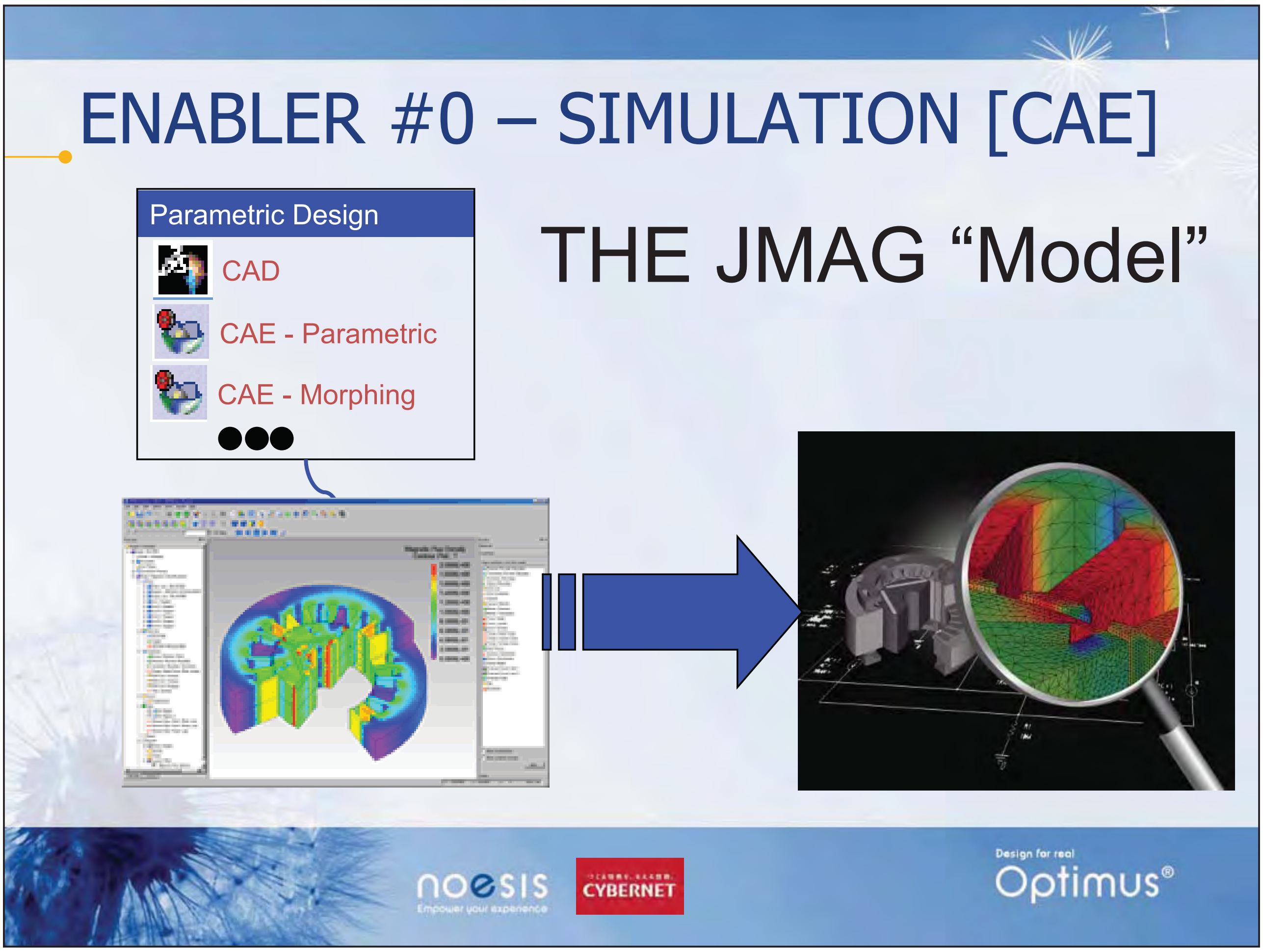
ENABLER #0 – SIMULATION [CAE]
Parametric Design
CAD
CAE - Parametric
CAE - Morphing
THE JMAG "Model"
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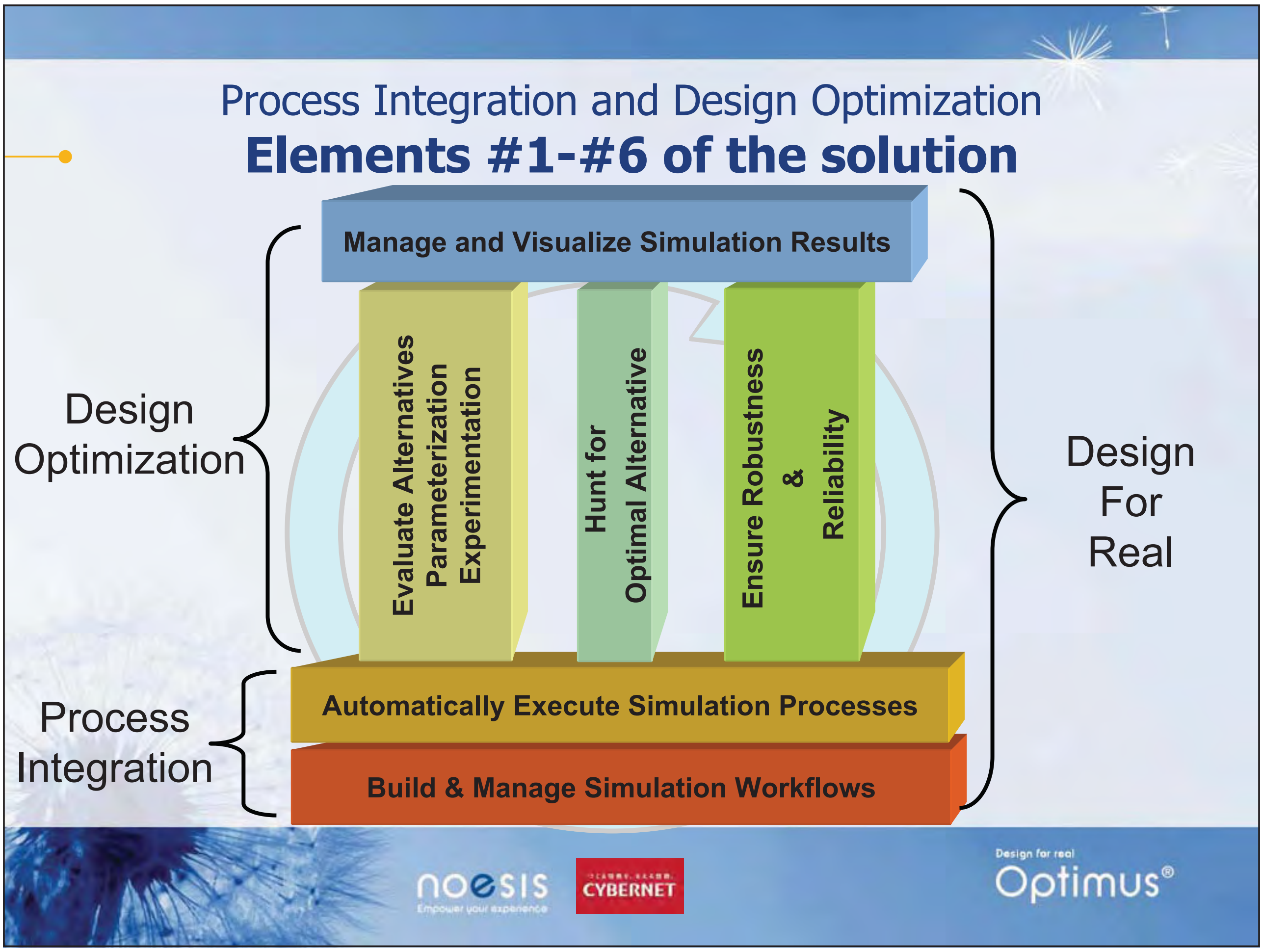
Process Integration and Design Optimization
Elements #1-#6 of the solution
Manage and Visualize Simulation Results
Evaluate Alternatives
Parameterization
Experimentation
Hunt for
Optimal Alternative
Ensure Robustness
&
Reliability
Design
Optimization
Design
For
Real
Process
Integration
Automatically Execute Simulation Processes
Build & Manage Simulation Workflows
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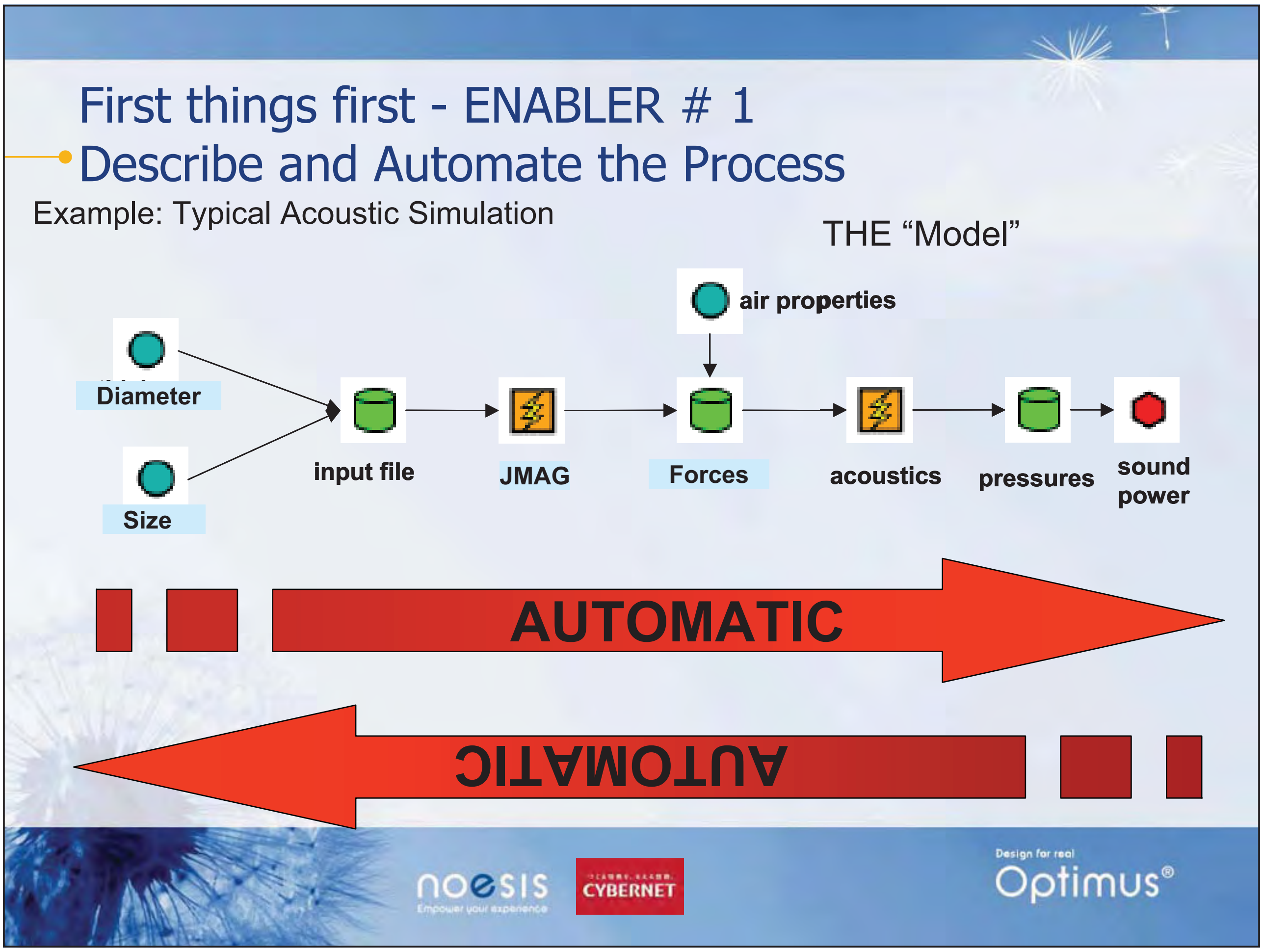
First things first - ENABLER # 1
Describe and Automate the Process
Example: Typical Acoustic Simulation
THE “Model”
air properties
Diameter
Size
input file
JMAG
Forces
acoustics
pressures
sound power
AUTOMATIC
AUTOMATIC
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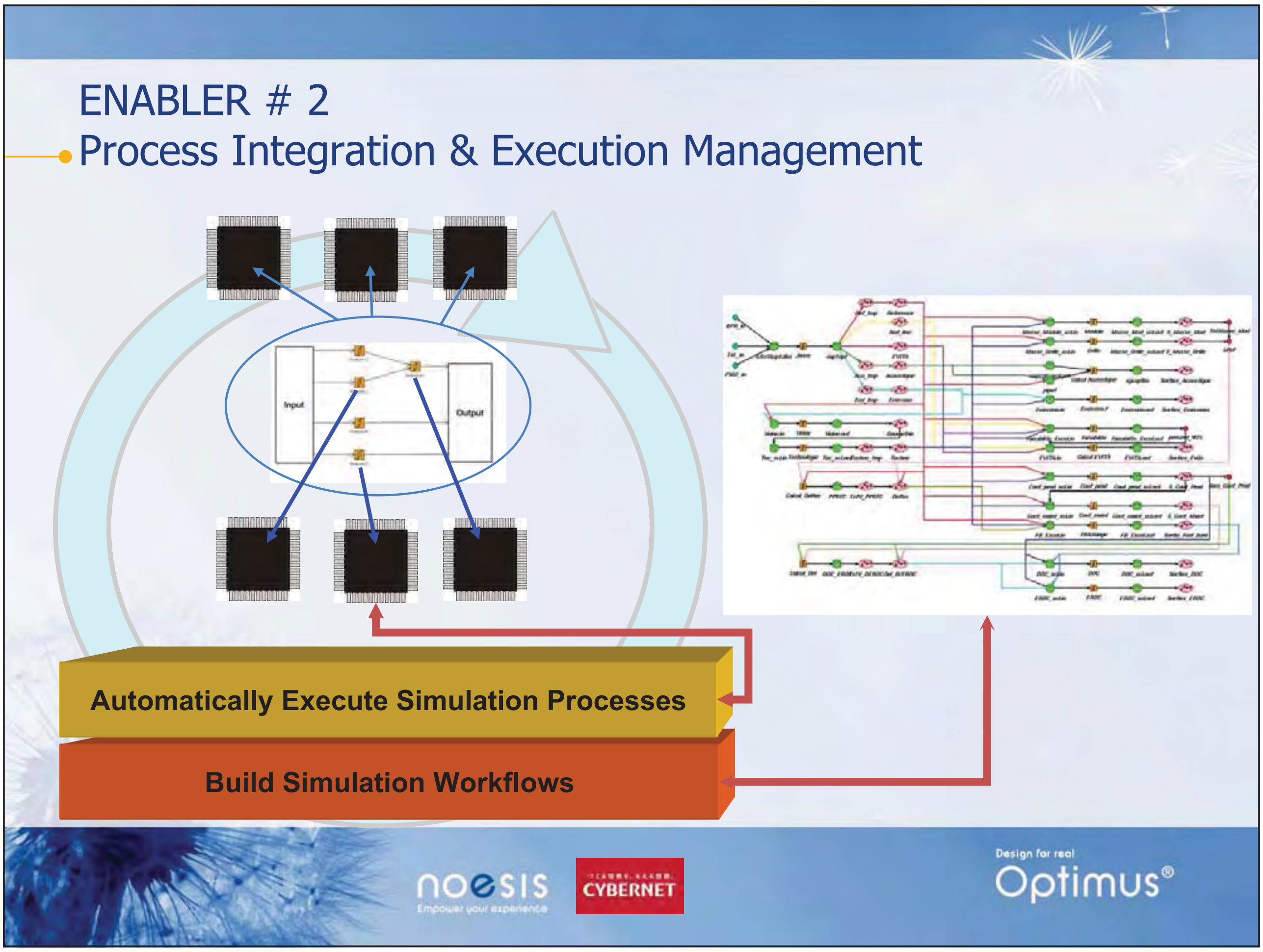
ENABLER # 2
Process Integration & Execution Management
Input
Output
Automatically Execute Simulation Processes
Build Simulation Workflows
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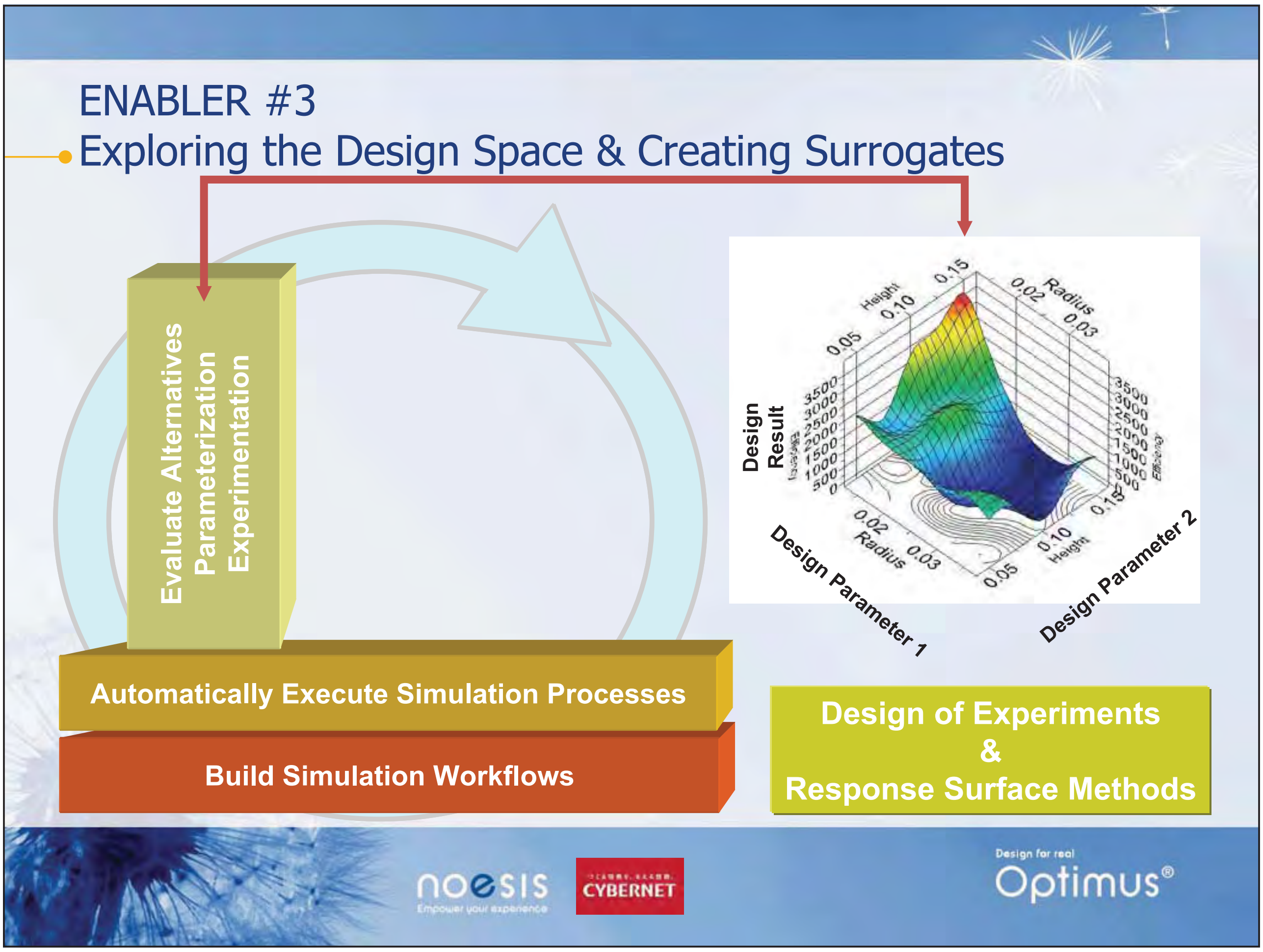
ENABLER #3
Exploring the Design Space & Creating Surrogates
Evaluate Alternatives
Parameterization
Experimentation
Automatically Execute Simulation Processes
Build Simulation Workflows
Design Result
Design Parameter 1
Design Parameter 2
Design of Experiments
&
Response Surface Methods
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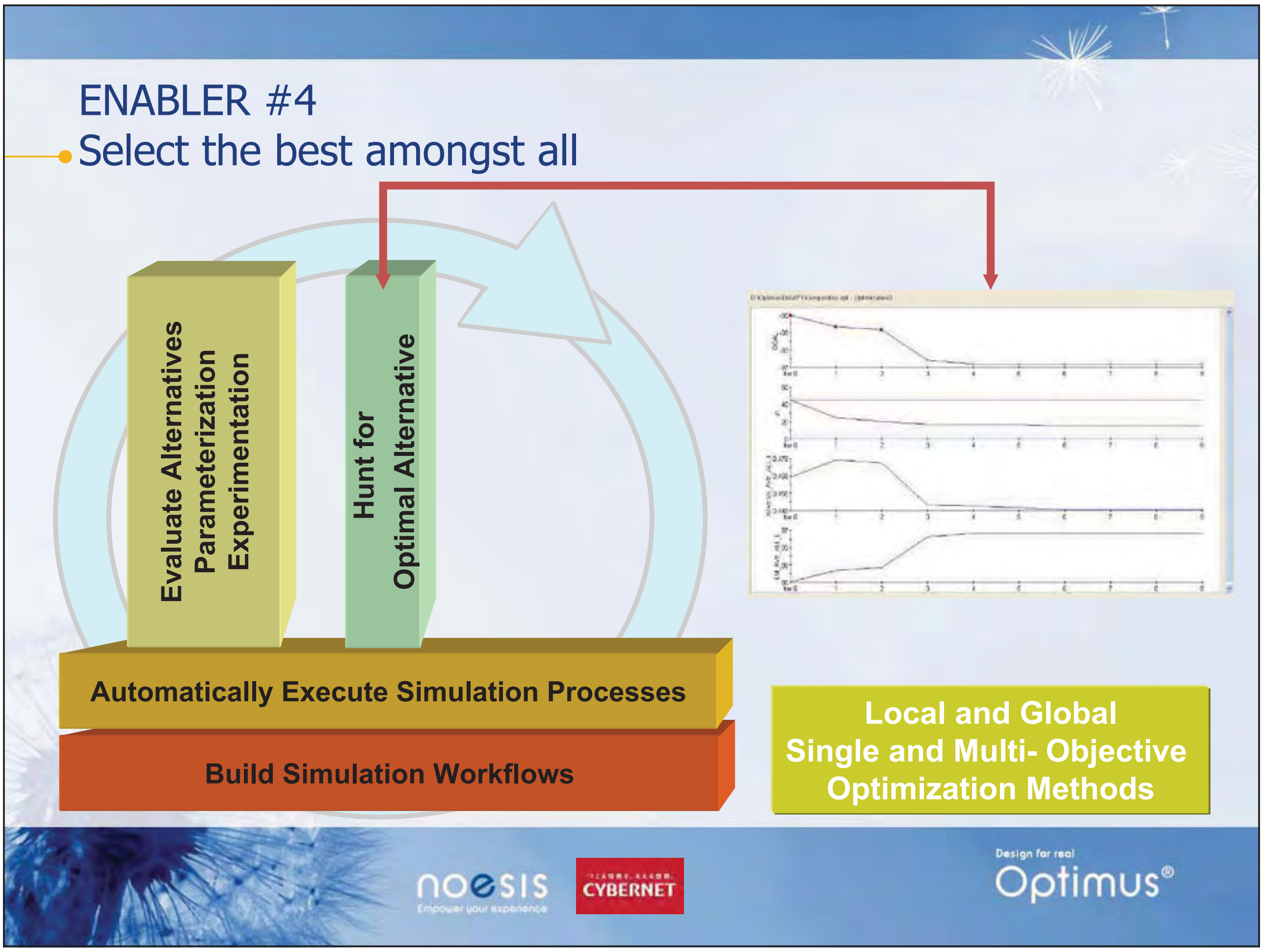
ENABLER #4
Select the best amongst all
Evaluate Alternatives
Parameterization
Experimentation
Hunt for
Optimal Alternative
Automatically Execute Simulation Processes
Build Simulation Workflows
Local and Global
Single and Multi- Objective
Optimization Methods
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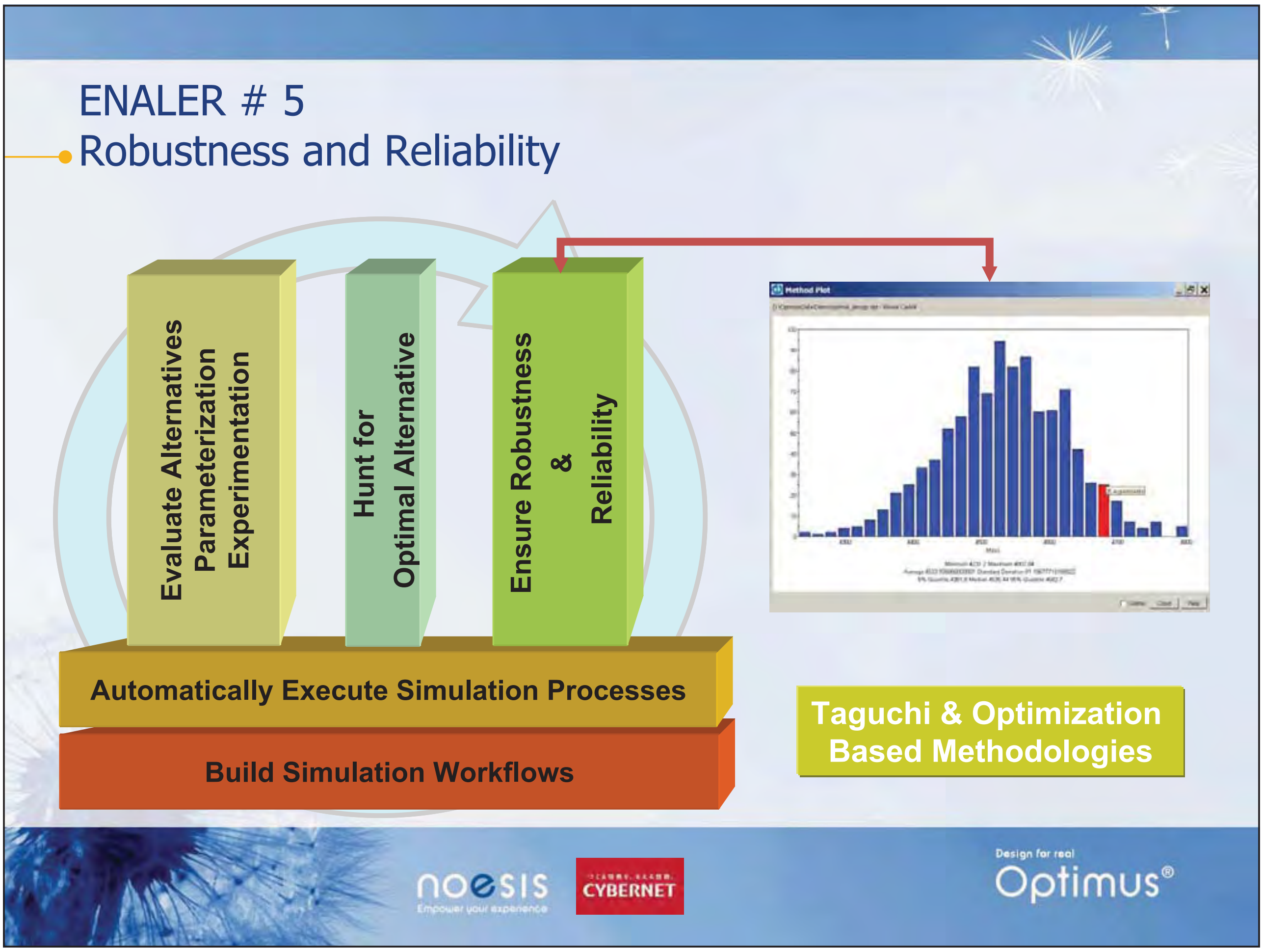
ENALER # 5
Robustness and Reliability
Evaluate Alternatives
Parameterization
Experimentation
Hunt for
Optimal Alternative
Ensure Robustness
&
Reliability
Automatically Execute Simulation Processes
Build Simulation Workflows
Taguchi & Optimization
Based Methodologies
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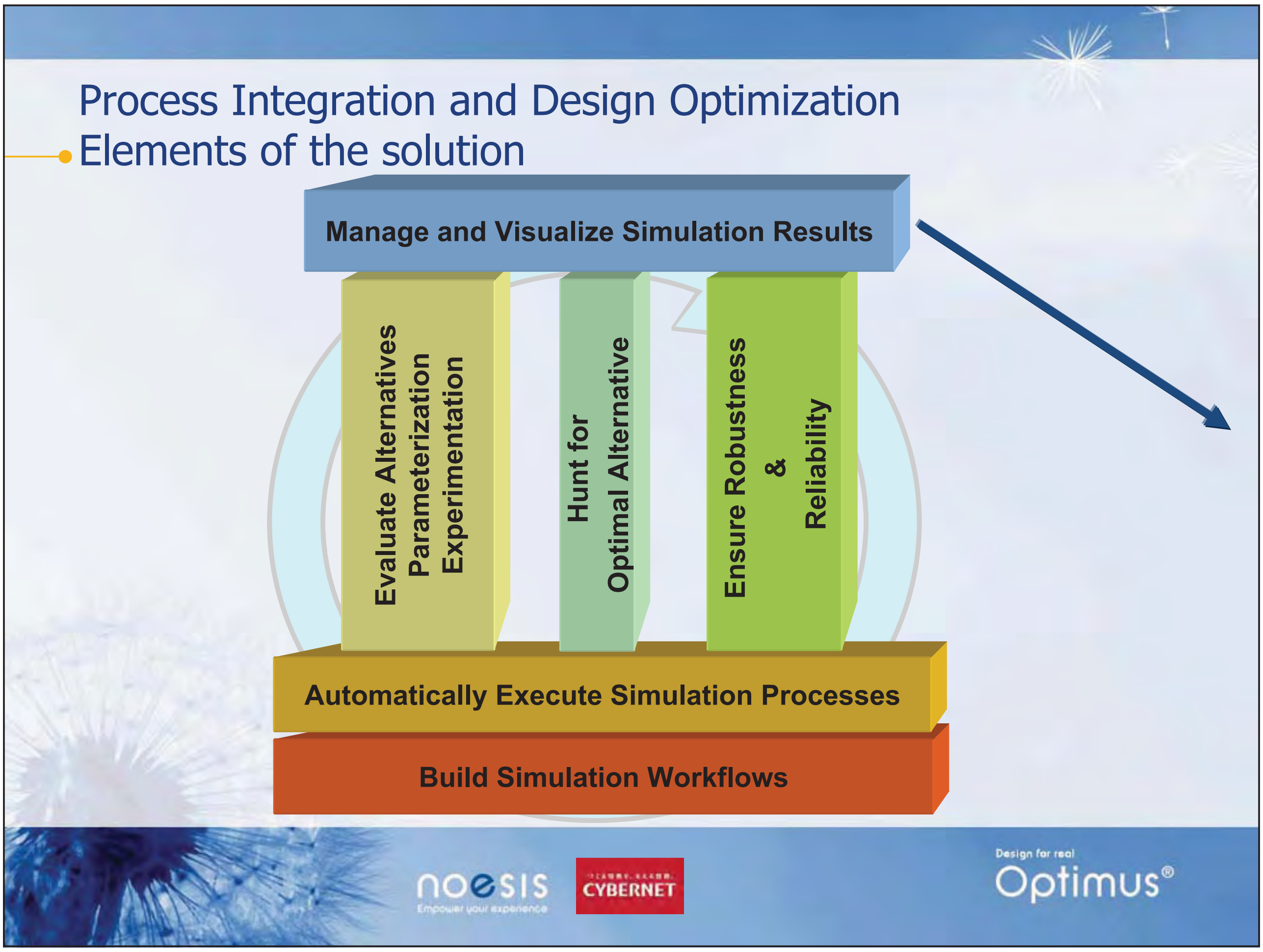
Process Integration and Design Optimization
Elements of the solution
Manage and Visualize Simulation Results
Evaluate Alternatives
Parameterization
Experimentation
Hunt for
Optimal Alternative
Ensure Robustness
&
Reliability
Automatically Execute Simulation Processes
Build Simulation Workflows
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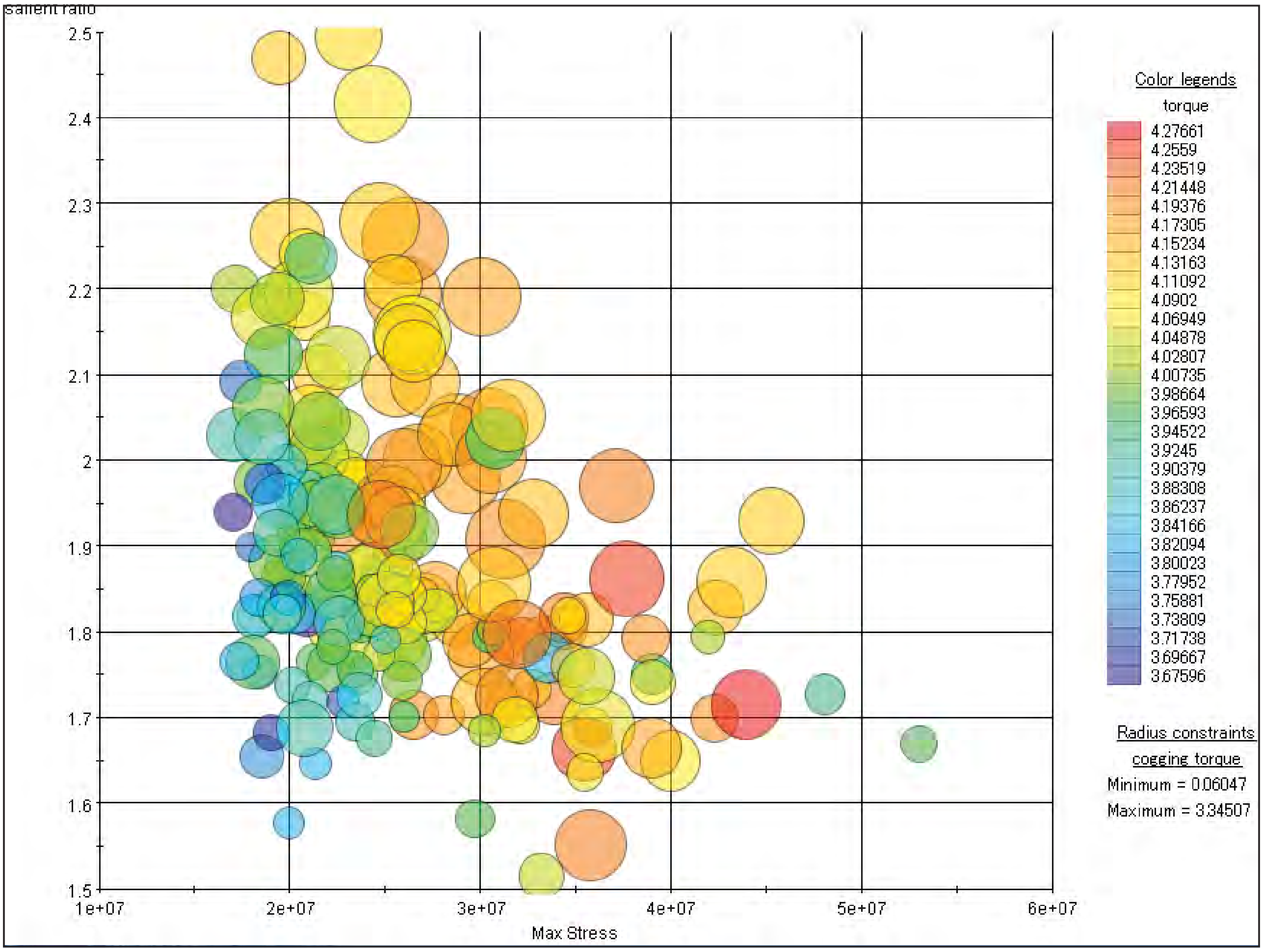

salient ratio
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1e+07
2e+07
3e+07
4e+07
5e+07
6e+07
Max Stress
Color legends
torque
4.27661
4.2559
4.23519
4.21448
4.19376
4.17305
4.15234
4.13163
4.11092
4.0902
4.06949
4.04878
4.02807
4.00735
3.98664
3.96593
3.94522
3.9245
3.90379
3.88308
3.86237
3.84166
3.82094
3.80023
3.77952
3.75881
3.73809
3.71738
3.69667
3.67596
Radius constraints
cogging torque
Minimum = 0.06047
Maximum = 3.34507

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Optimus: Connect your simulation
Noesis Optimus Rev 7
MATLAB
ABAQUS
ANSA
ADV
LMS
ENGINEERING INNOVATION
Altair
MSC Software
Simulate More
DASSAULT SYSTEMES
JMAG
SIM
CAD-CAE Engineer
Maplesoft
moldflow
SIEMENS
PTC
RICARDO
MSC
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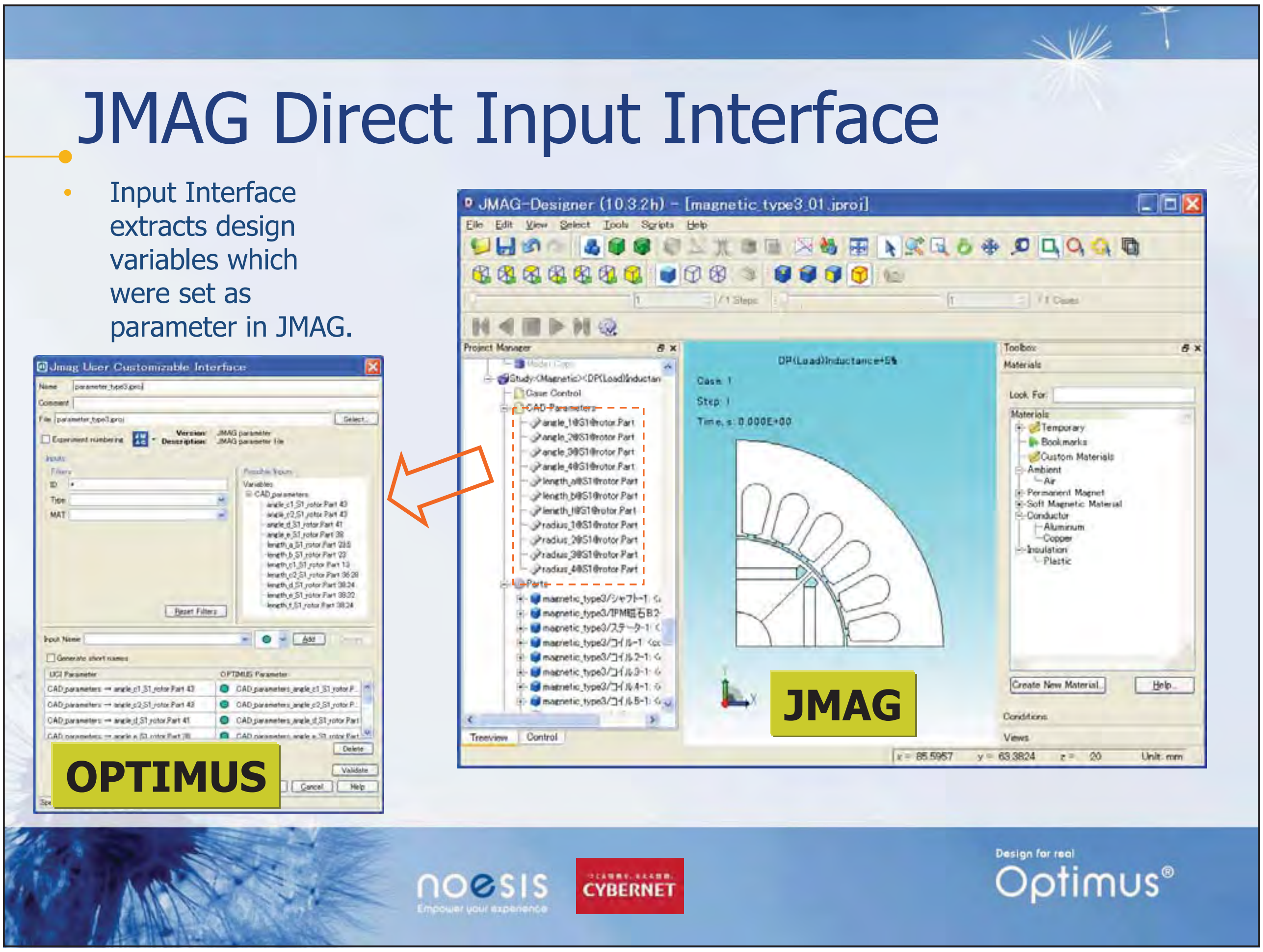
JMAG Direct Input Interface
Input Interface extracts design variables which were set as parameter in JMAG.
Jmag User Customizable Interface
JMAG-Designer (10.3.2h) - [magnetic_type3_01.jproj]
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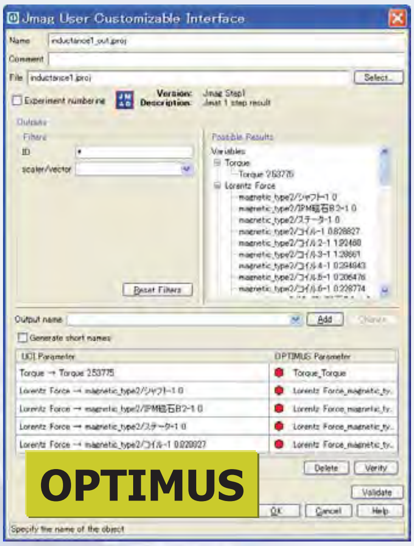
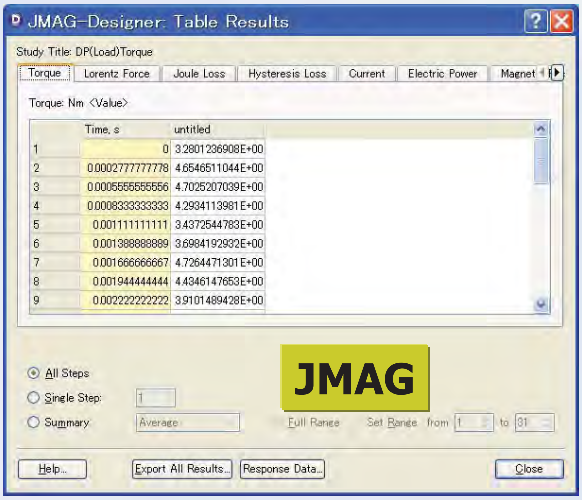
JMAG Direct Interface

- Output Interface extracts all results in jproj file.





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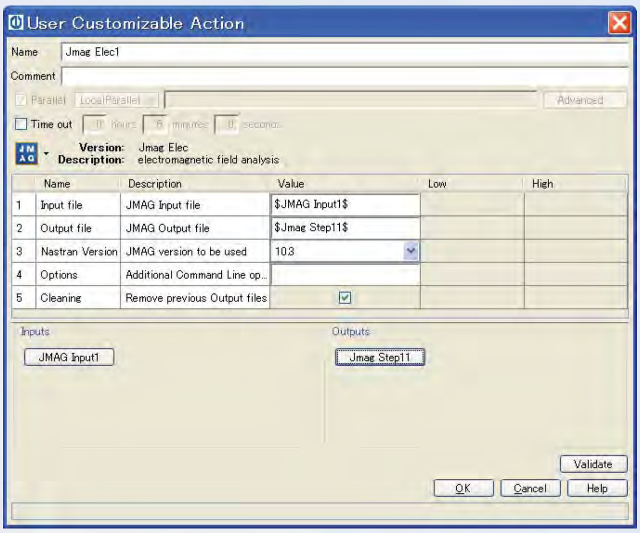
JMAG Direct Interface

- JMAG Action Icon



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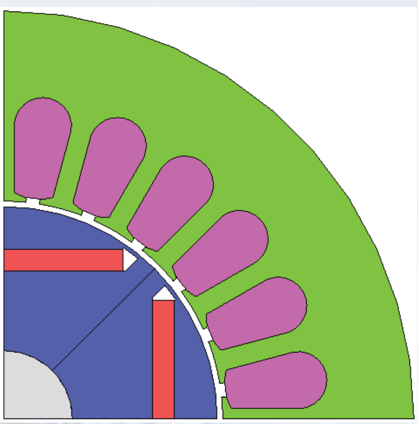
JMAG Analytical Model

Interior Permanent Magnet Motor (IPM motor)
Implanted magnet
three-phase synchronism motor



motor specification

number of pole	4
number of slot	24
wire connection	Y-shaped
rotor radius(mm)	78
stator radius(mm)	150
gap length(mm)	1
thickness(mm)	50
coil tubing	distributed winding
coil turns(turn/1coil)	32
phase resistance(Ω)	0.46
number of revolutions(rpm)	4800 (centrifugal force : 10000rpm)

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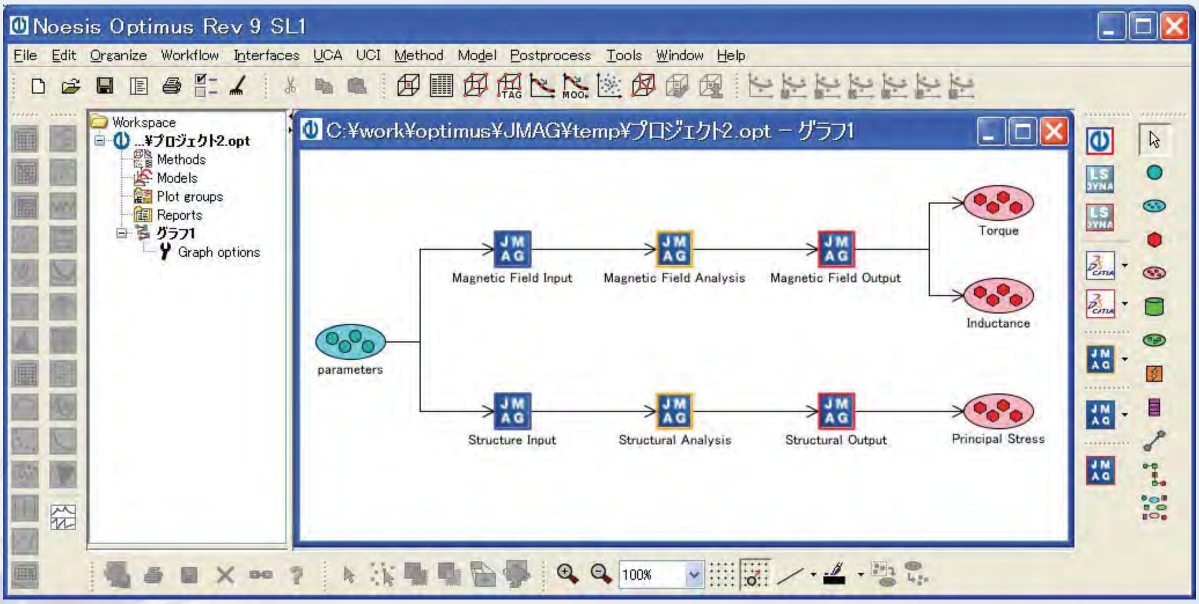
Optimus Automation



Optimization

Target: Multi-Objective Optimization

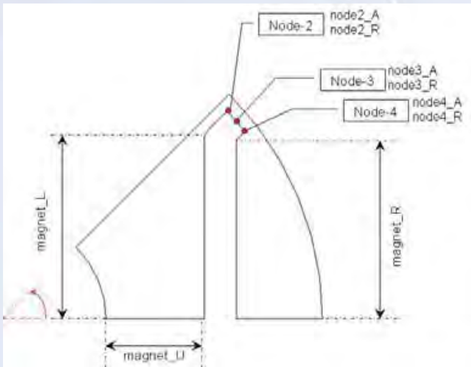
Maximize: Salient ratio of Inductance

Minimize : Cogging Torque

Constraints:

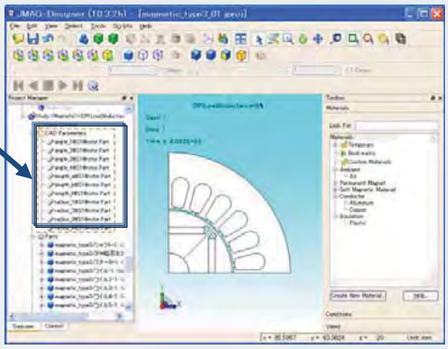
Max Stress upper limit : 88 MPa

Torque lower limit : 3.8 Nm

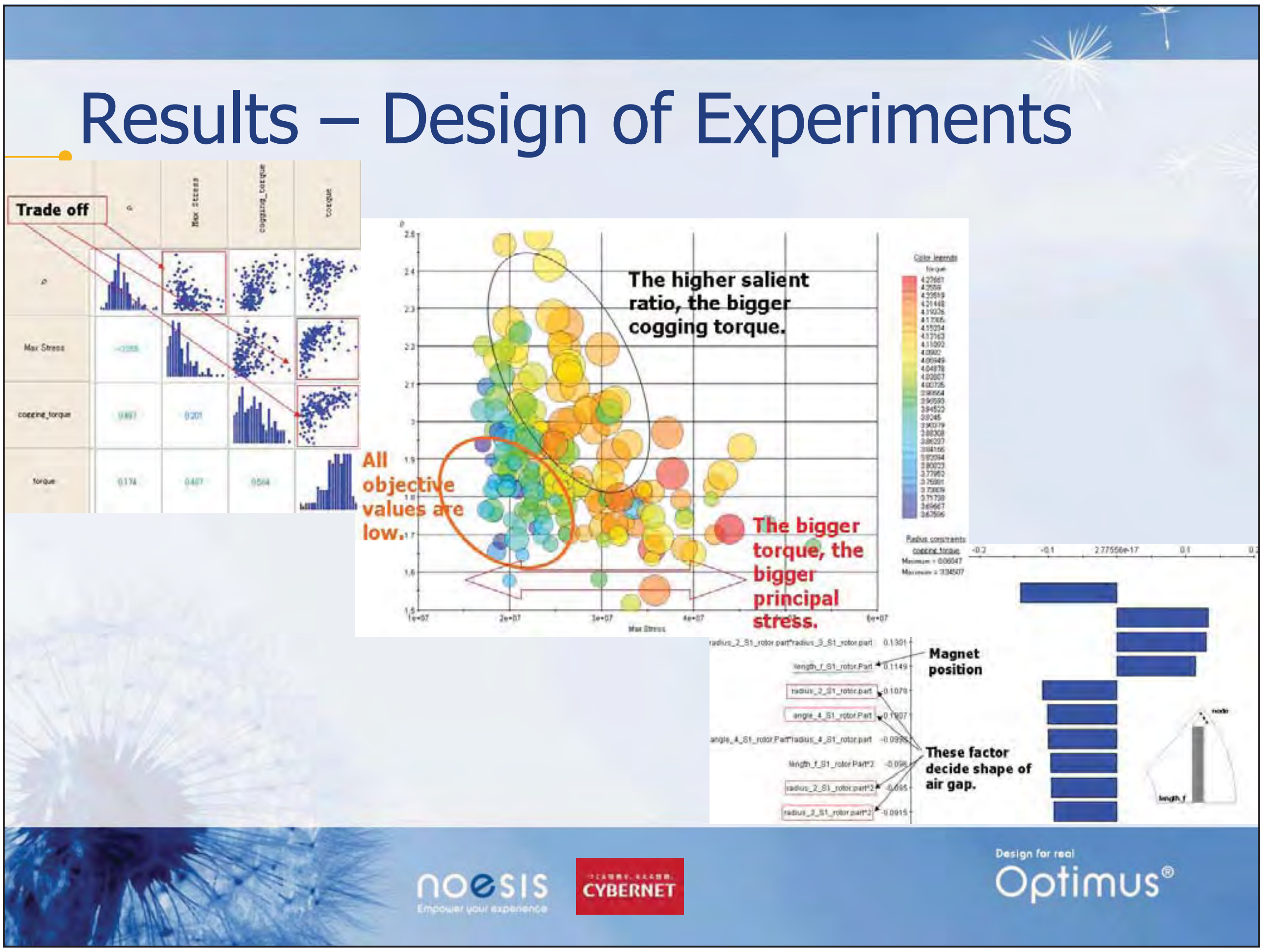


Design variable :

node1_A, node1_R
node2_A, node2_R
node3_A, node3_R
node4_A, node4_R
magnet_L
magnet_R
magnet_U



	Range of Design variable	
	Low	High
node1_A	42	44
node2_A	42	44
node3_A	40	44
node4_A	30	40
magnet_L	21.6	24
magnet_R	18	23
magnet_U	11	14.5
node1_R	34.9	38.4
node2_R	35	38.5
node3_R	35	38.5
node4_R	36	38.5



Results – Design of Experiments
Trade off
All objective values are low.
The higher salient ratio, the bigger cogging torque.
The bigger torque, the bigger principal stress.
Magnet position
These factor decide shape of air gap.
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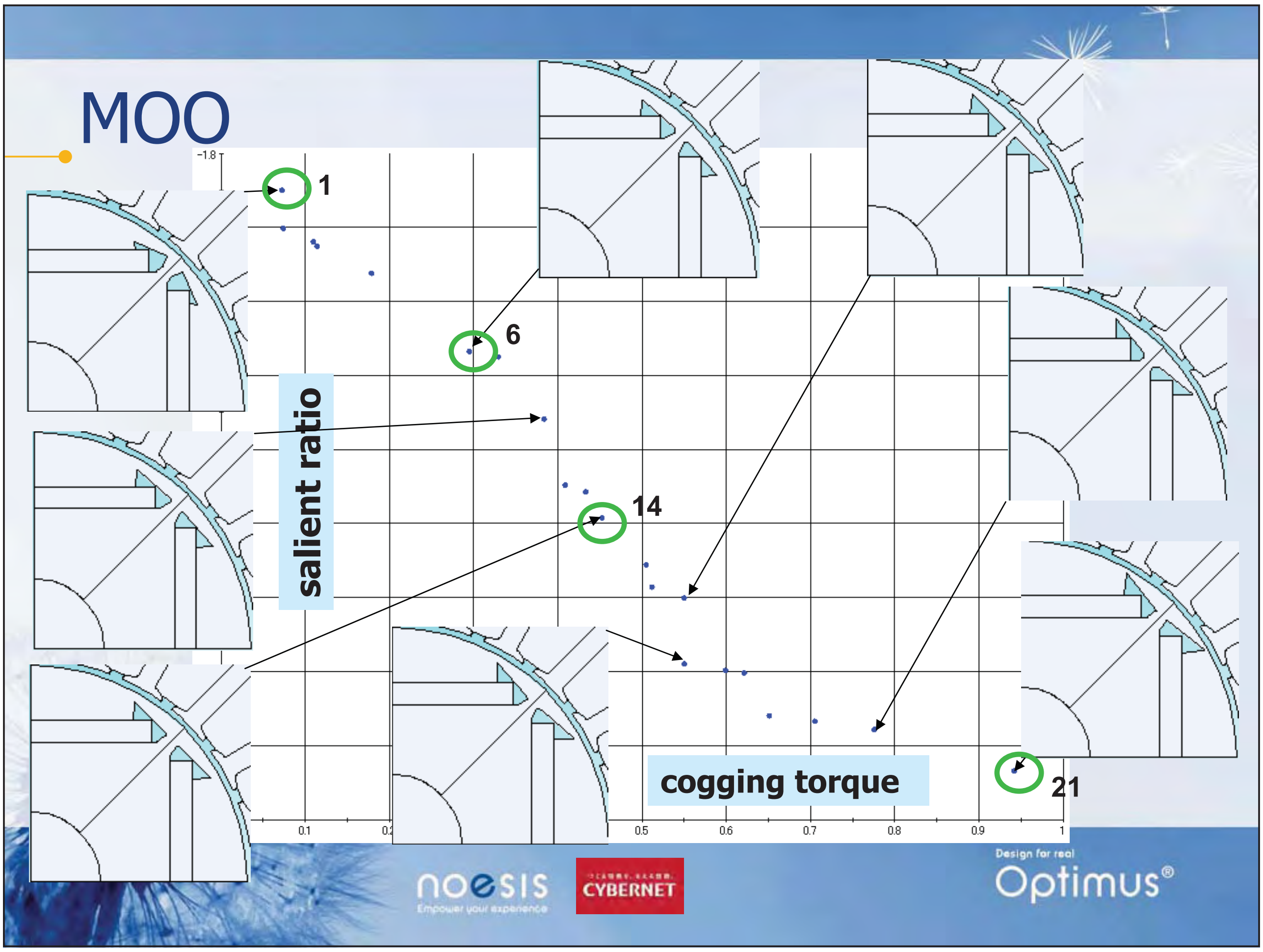

MOO
1
6
14
21
salient ratio
cogging torque
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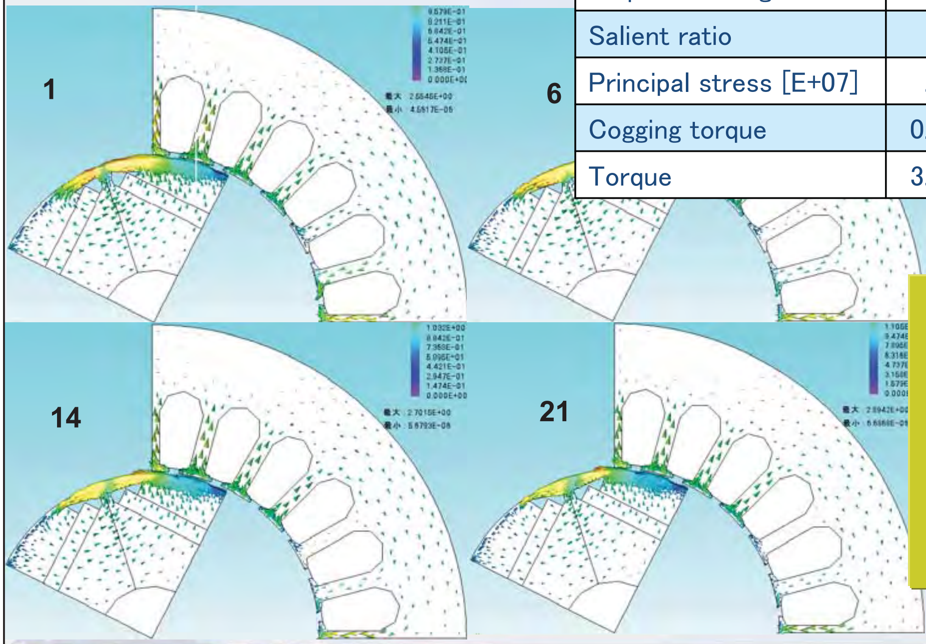
Density of magnetic flux of Optimal Designs

Optimal Design	1	6	14	21
Salient ratio	1.84	2.06	2.40	2.63
Principal stress [E+07]	2.11	1.81	1.69	1.78
Cogging torque	0.071	0.294	0.549	0.941
Torque	3.951	3.831	3.990	4.091



Significant 10% or more improvement from the starting design

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Ready for Questions

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