EXPLORE DESIGN PERFECTION

Design Optimization - Essential to a Better Product

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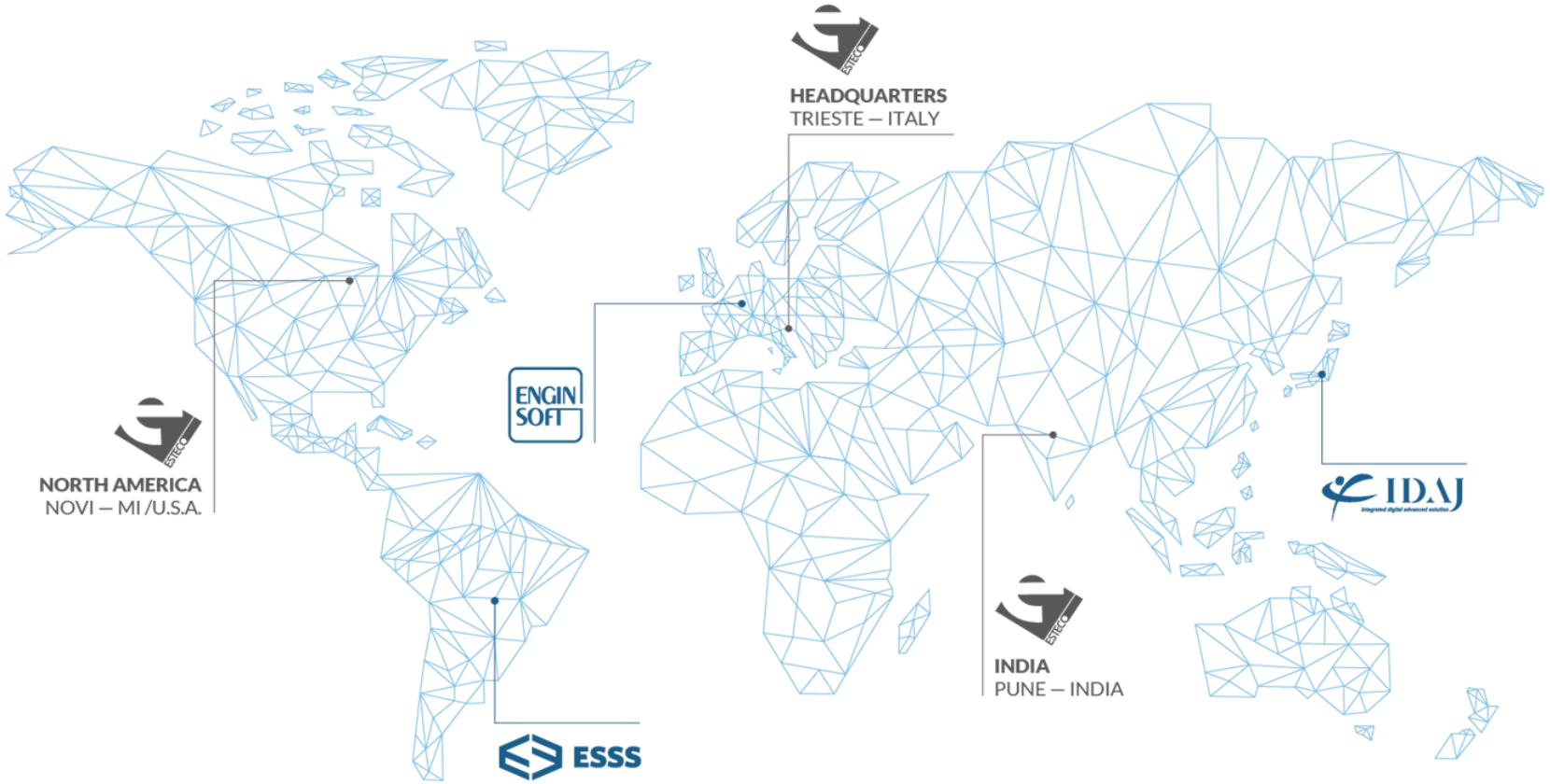
Outlines

- What does ESTECO do?
- What is design optimization?
- Why do we need Design Optimization?
  - Design Optimization applications in the US
- Looking into the future

About ESTECO



ESTECO is an independent technology provider delivering first-class software solutions aimed at perfecting the simulation-driven design process. With more than 16 years' experience, we support engineers and companies in designing better, more efficient products

ESTECO Technology

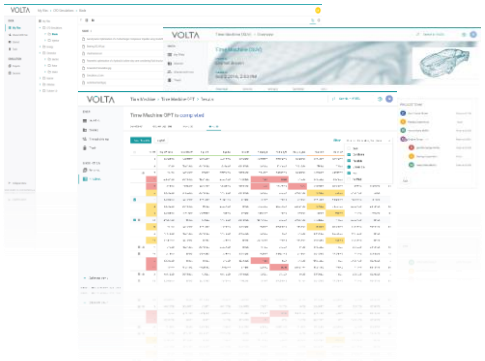
Our aim is to increase creativity and decrease tedium in engineering analysis by developing and maintaining cutting-edge software that enables integration, optimization and advanced data analytics.

Process Integration, Design Optimization, and Data Analytics Software (Desktop solution)

Increases efficiency of design simulation tools

inspires decision making

accelerates product innovation



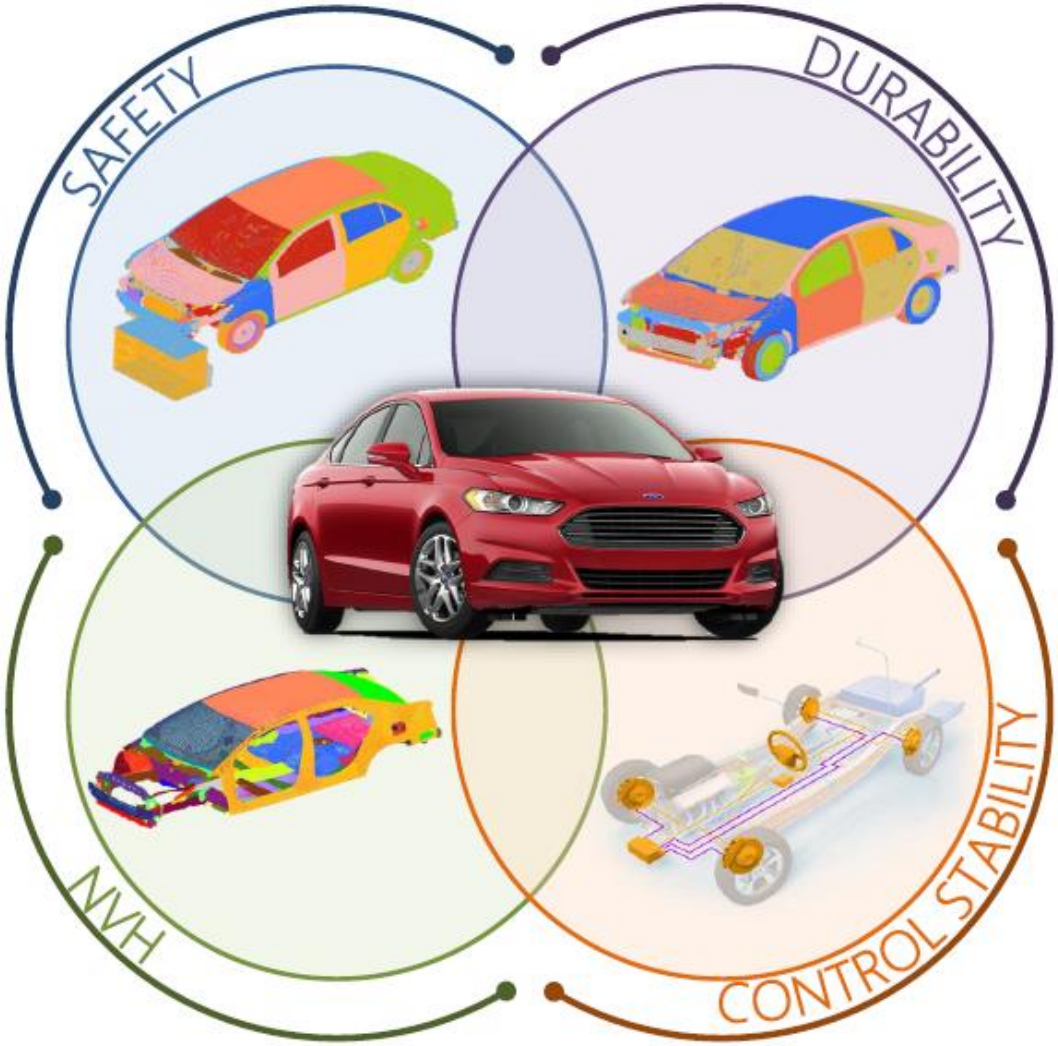
Web-based, collaborative MDO and decision making platform

Do a search of “设计优化” (Design Optimization) on Baidu

多学科设计优化： **Multidisciplinary Design Optimization**

Multidisciplinary Design Optimization in Automotive

- **Requires analyses in multiple disciplines**
  Involves multiple subsystems and/or components



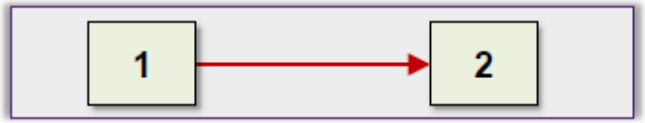
- Fusion SE 2014 image from Ford Motor Co
- FEA model images provided by Dr. Lei Shi, Shanghai Jiao Tong University
- Control system image from StabiliTrak

Z Jiang，S Chen，DW Apley, W Chen, Journal of Mechanical Design, 2016, 138(8)

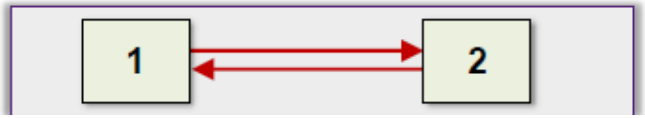
Multidisciplinary Design Optimization in Aerospace

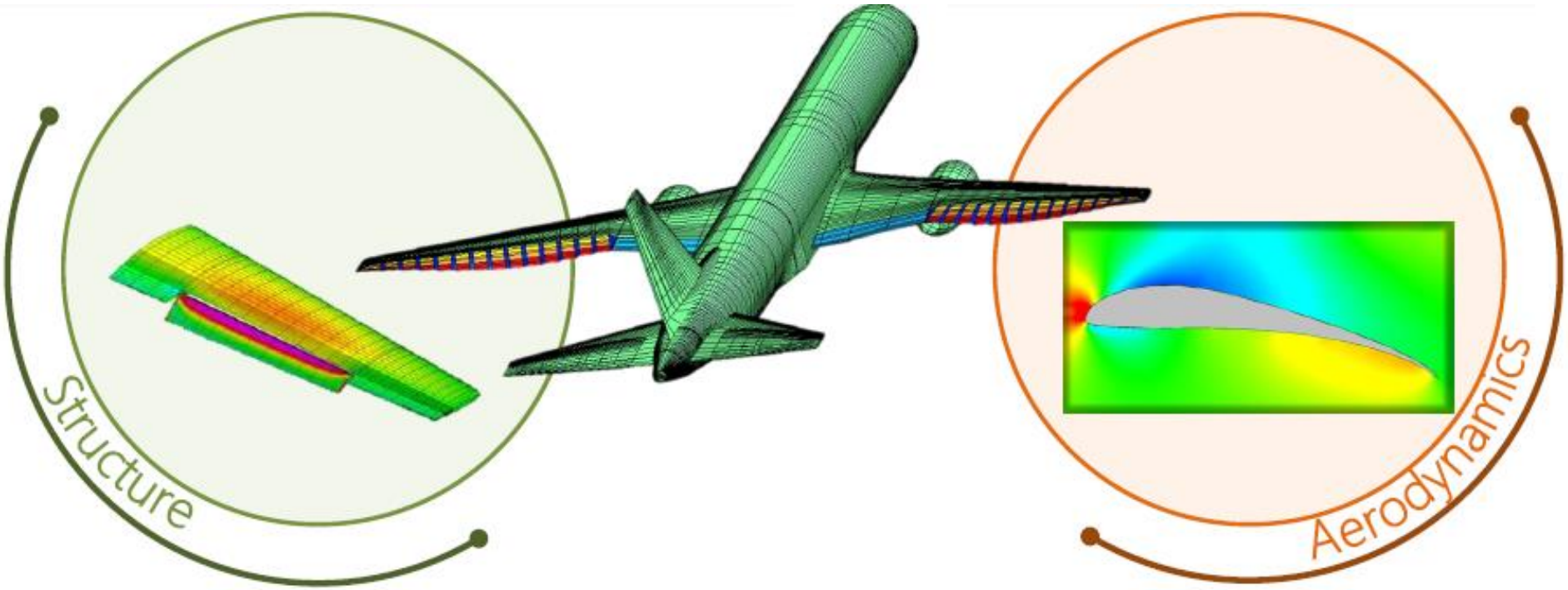
- **Requires analyses in multiple disciplines**
  Involves multiple subsystems and/or components

- **Interdisciplinary couplings**
  - Feed-forward Coupling



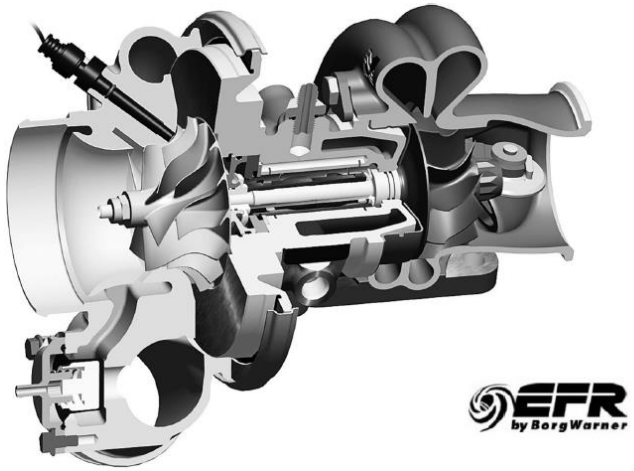
  - Feedback Coupling

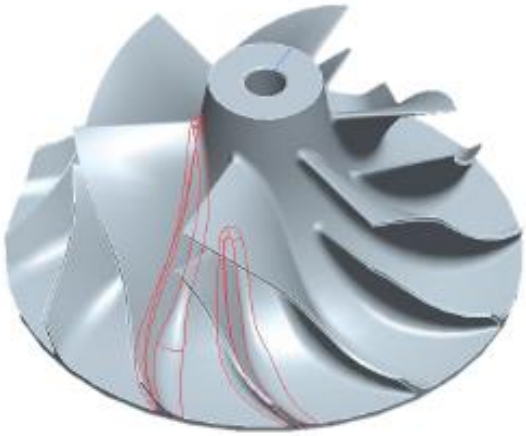




Z Jiang，S Chen，DW Apley, W Chen, Journal of Mechanical Design, 2016, 138(8)

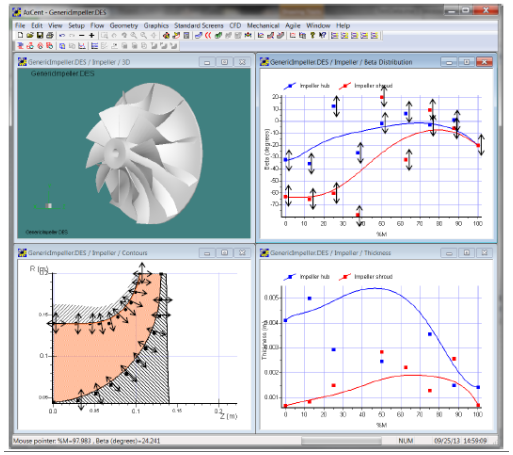
Application 1: Aerodynamic Optimization of a Turbo Compressor



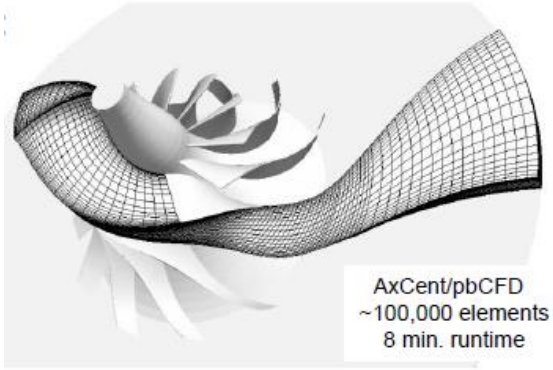


Lotz, R., Optimization of a Turbo Charger Compressor using AxCent and modeFRONTIER, BorgWarner Turbo Systems, presented on Esteco North America's user meeting on November 11, 2015

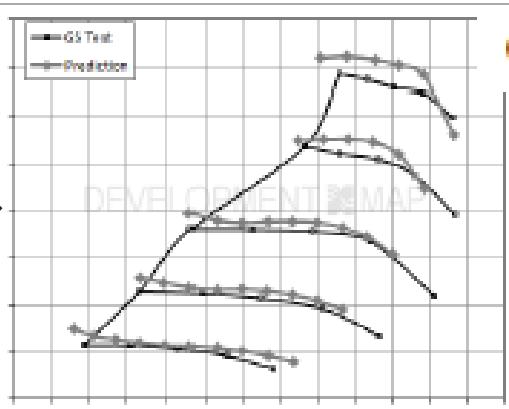
Method and process



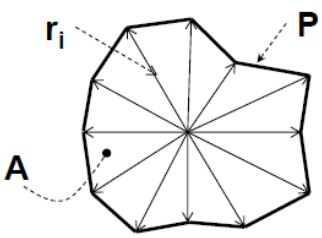
1. Change geometry (AxCent)

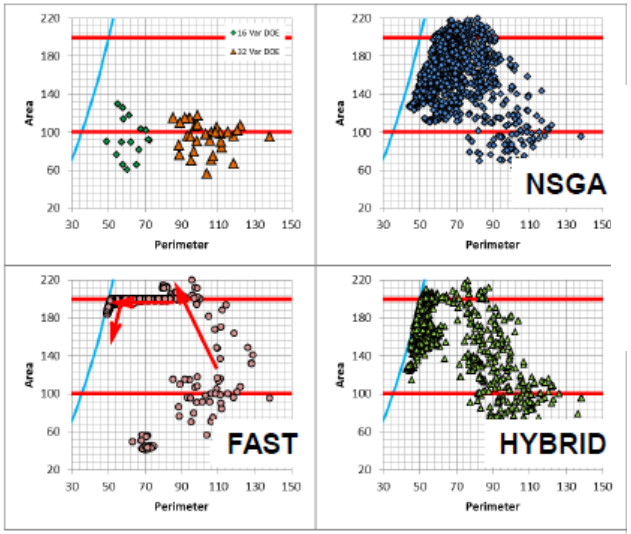


2. Generate Mesh (AxCent)

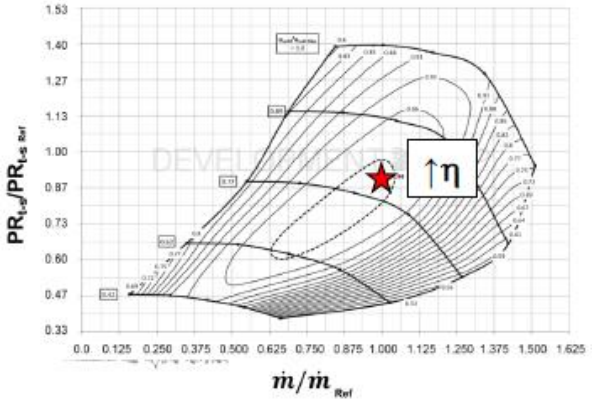


3. Make sure CFD analysis is accurate (AxCent)





4. Optimization algorithm benchmark using a simple problem (modeFRONTIER)



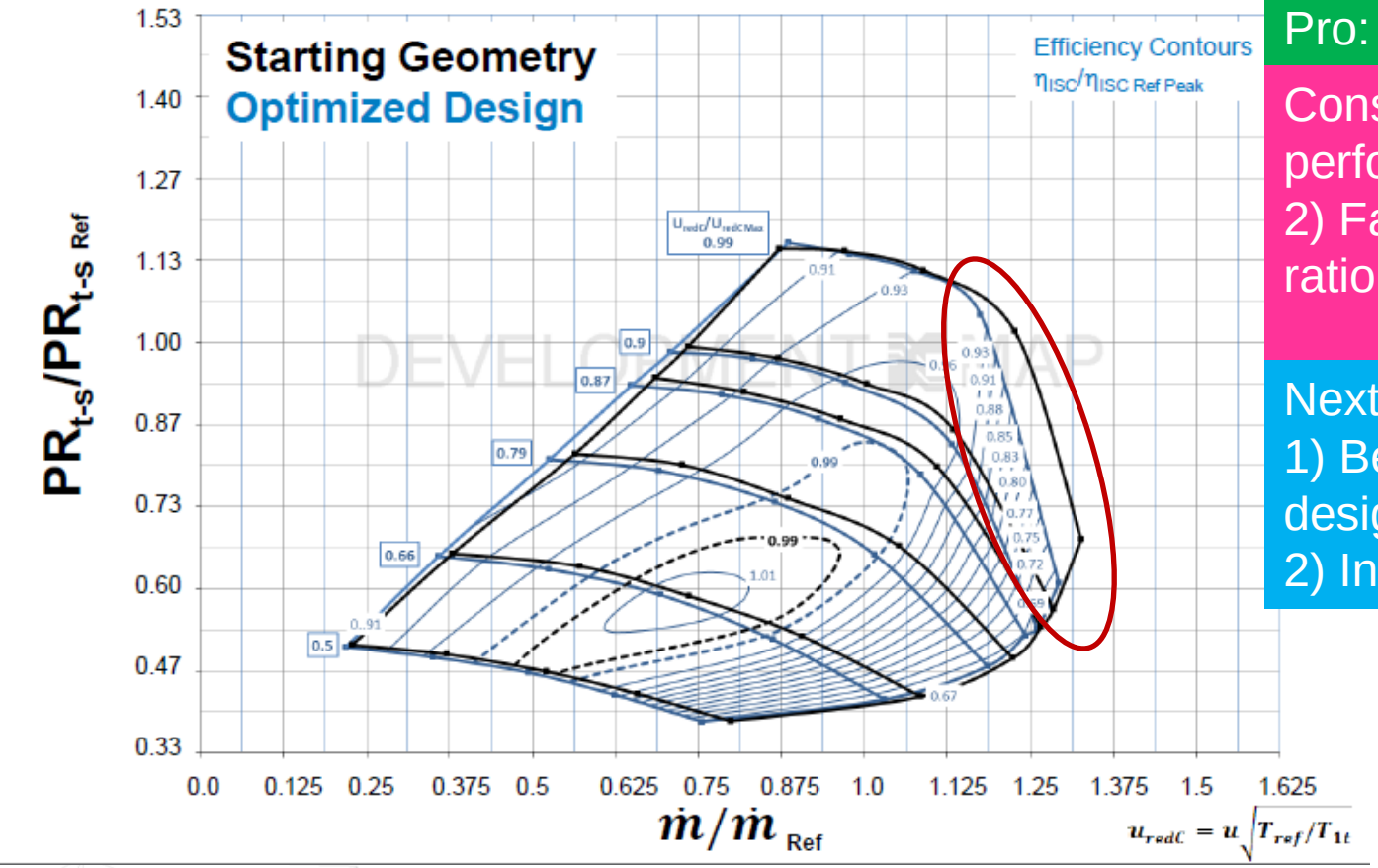
5. Perform Optimization on real problem (modeFRONTIER + AxCent)

Optimization trial 1

Objective: *maximize efficiency*

Result constraints: *Pressure ratio min*

Optimizer: *NSGA and Simplex*



Pro: efficiency improvement

Cons: 1) high speed performance loss
2) Fail to meet pressure ratio target

Next try:
1) Better exploration of design space
2) Influence pressure ratio

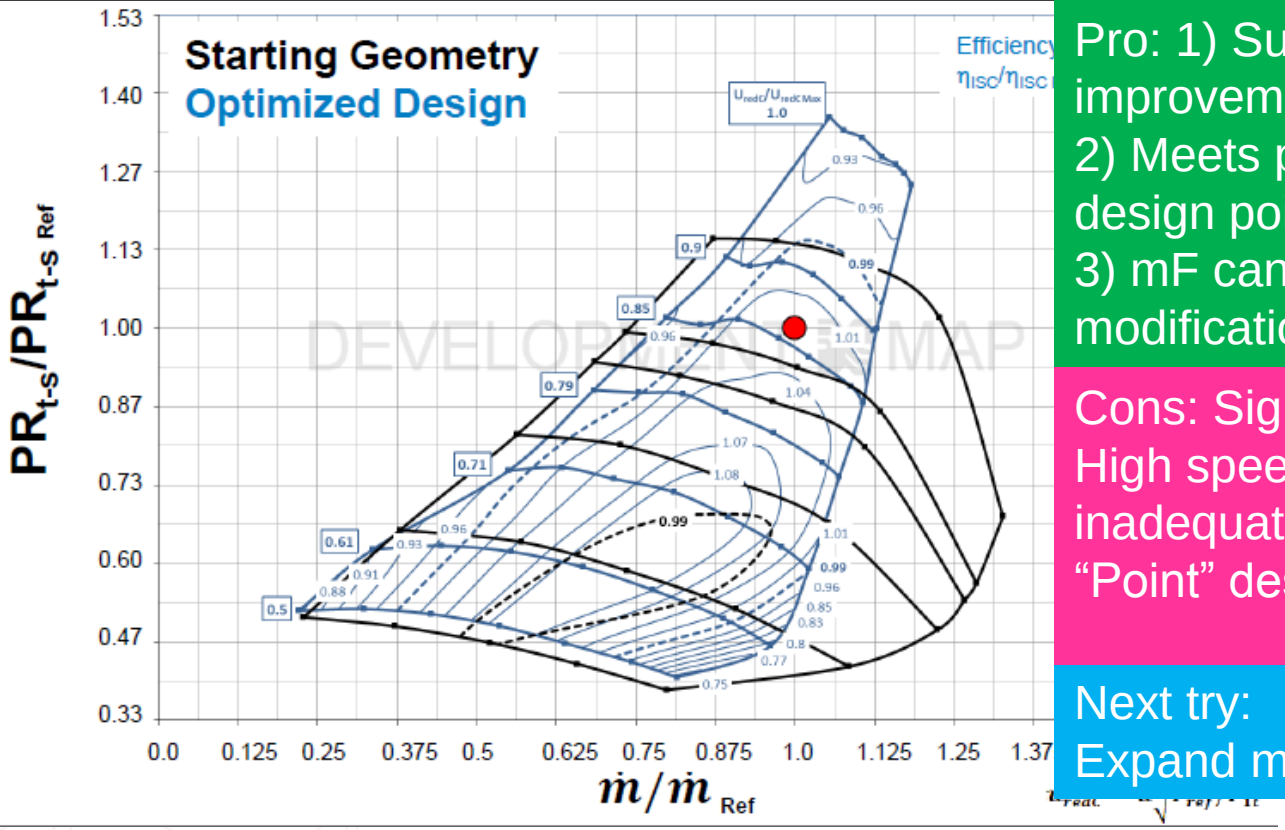
Optimization trial 2

Objective: *maximize Efficiency and Pressure Ratio on inducer and exducer*

Optimizer: *Hybrid (GA+SQP)*

Input Constraints: *Geometric constraints*

Result constraints: *Pressure Ratio minimum and maximum*



Pro: 1) Substantial efficiency improvement
2) Meets pressure ratio target at design point
3) mF can make substantial modifications to an existing design

Cons: Significant loss of map width
High speed performance is inadequate.
"Point" design, not of practical use

Next try:
Expand map width

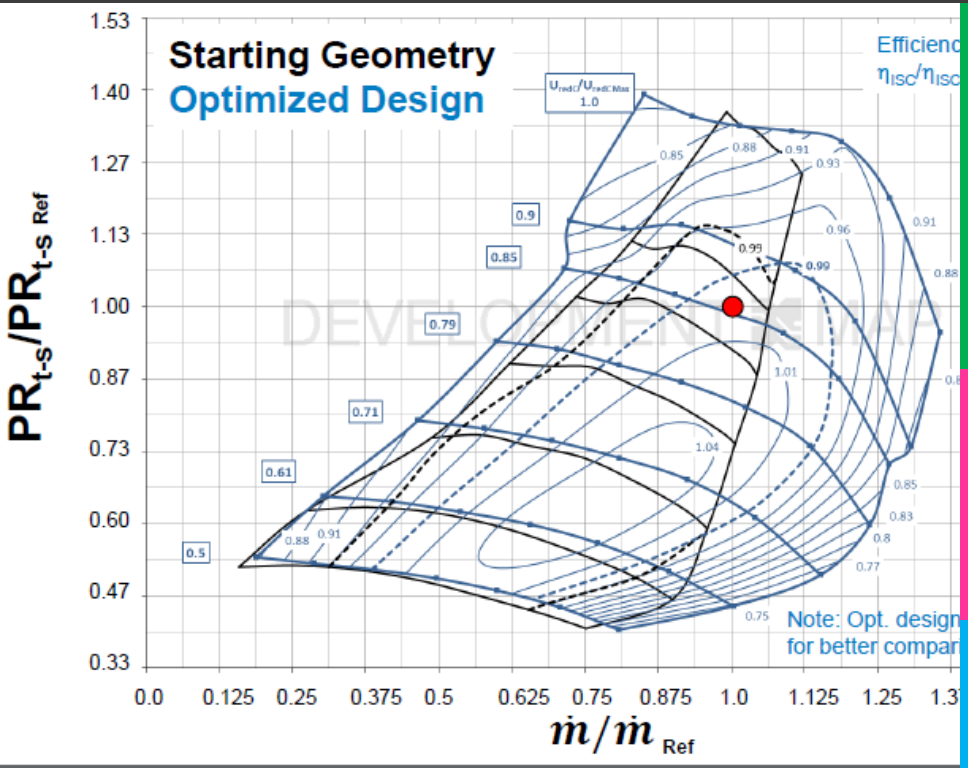
Optimization trial 3

Objective: *maximize Efficiency Target function and Pressure Ratio*

Optimizer: *Hybrid (GA+SQP)*

Input Constraints: *Geometric constraints on inducer and exducer, fixed diffuser diameter*

Result constraints: *Pressure ratio minimum and maximum*



Pros:1) Substantial map width improvement
2) mF can make substantial modifications to an existing design
3) This is getting close to being a useful design!

Cons:
1) Some loss in peak efficiency.
2) Map has shifted to higher mass flow rates.

next try:
1) More control over details of the map
2) Create a practical compressor

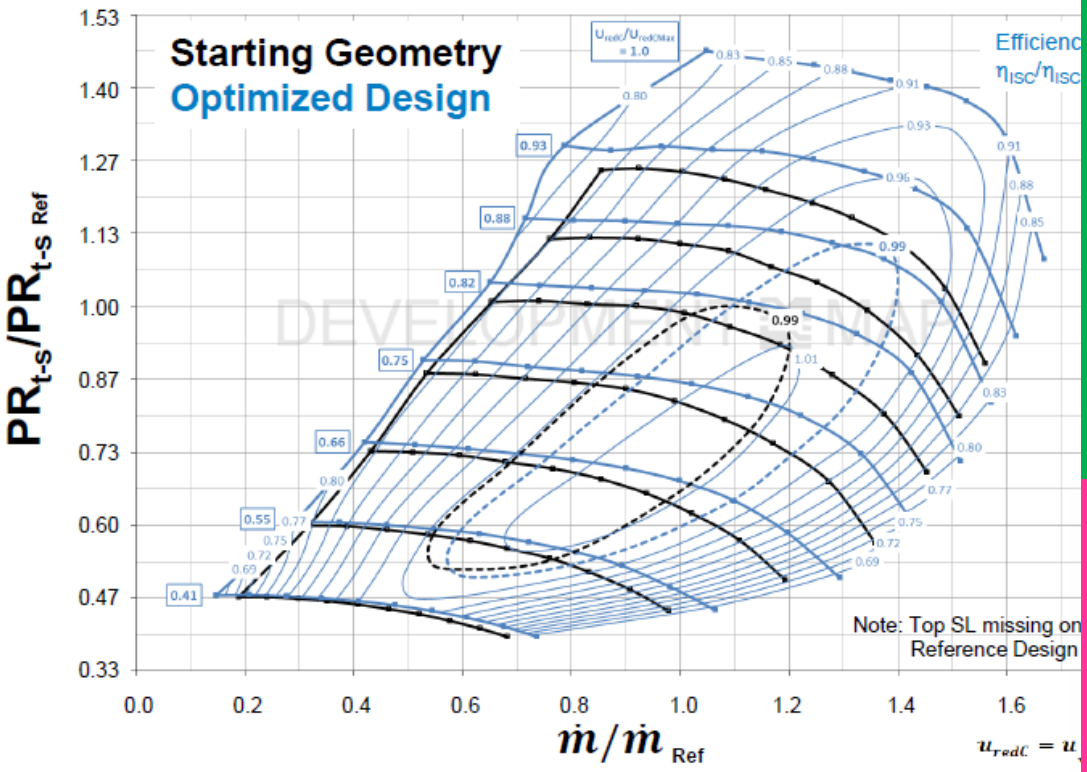
Optimization trial 4

Objective: *maximize Efficiency Target function and Pressure Ratio, minimize surge Target Function*
maximize choke mass flow rate

Optimizer: *Hybrid (GA+SQP)*

Input Constraints: *Geometric constraints on inducer and exducer, fixed diffuser diameter*

Result constraints: *Pressure ratio minimum and maximum, and efficiency*



Pros:
1) Improvement on all sides of the map over the legacy design.
2) Higher peak efficiency
3) Higher specific pressure ratio
4) Higher choke mass flow
5) Better surge behavior

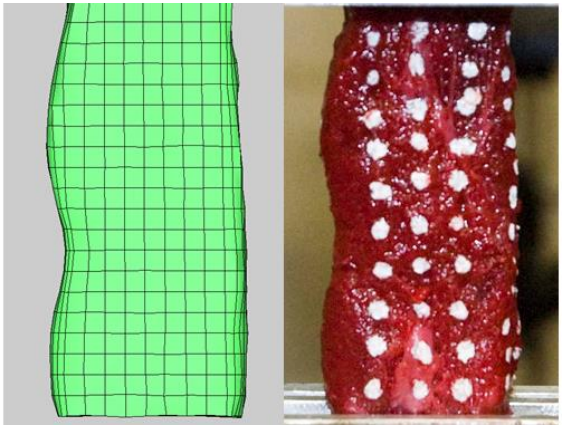
Cons:
1) Efficiency islands moved to higher mass flow.
2) Structurally less capable than the legacy design, MDO is next

What does this application tell us?

- Optimization formulation determines optimization results quality

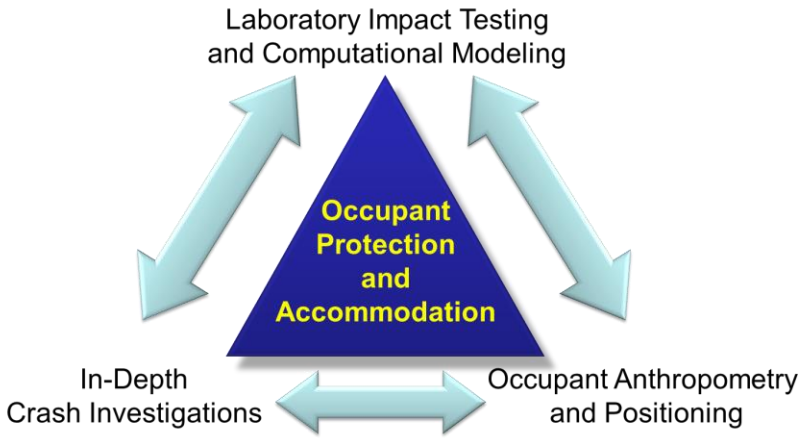
- Keep learning from optimization – “optimize” the optimization formulation!

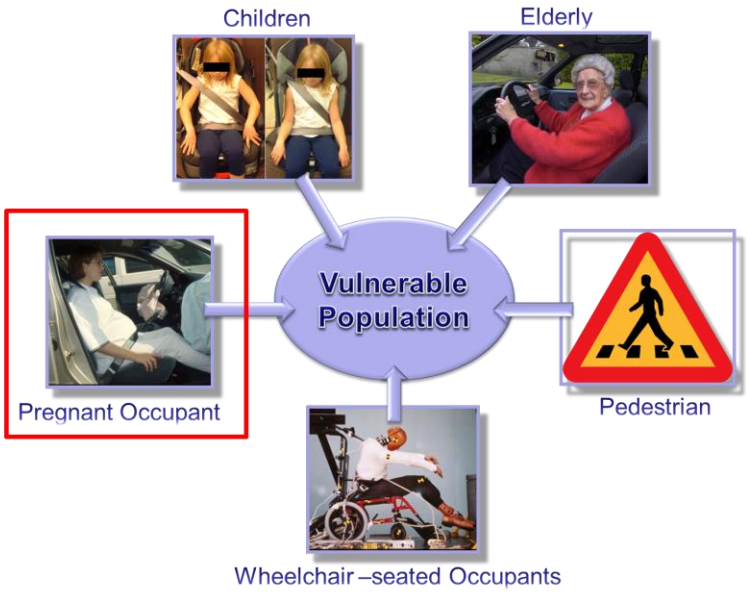
Application 2: A Stochastic Visco-hyperelastic Model of Human Placenta Tissue for Finite Element Crash Simulations

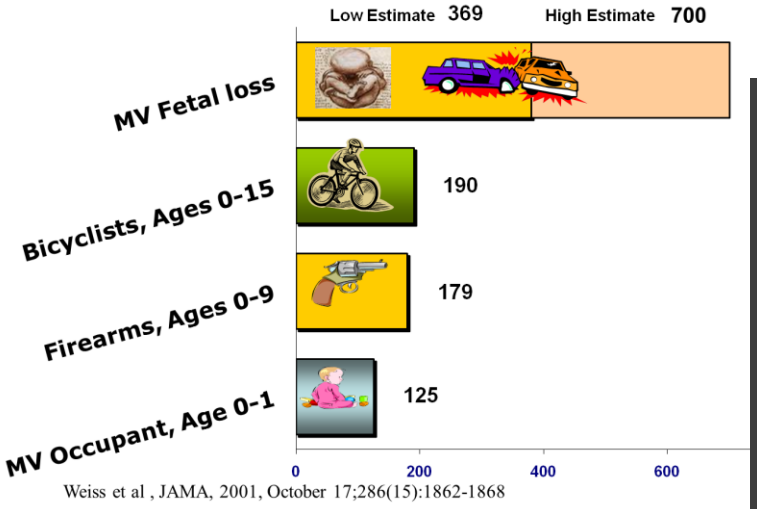


Hu, J., Klinich, K.D., Miller, C.S. et al. Ann Biomed Eng (2011) 39: 1074. doi:10.1007/s10439-010-0222-0

Why do we need to build a computational models of the human placenta?







Weiss et al , JAMA, 2001, October 17;286(15):1862-1868

Motor-vehicle crashes are the leading cause of fetal deaths from maternal trauma in the US, and placental abruption is the most common cause of traumatic fetal death. (Weiss 2001)

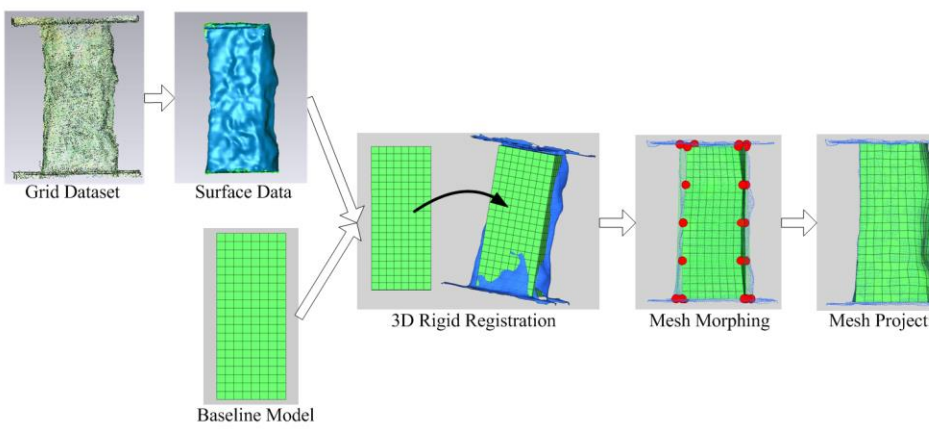
Computational models of pregnant women are needed to evaluate the risk of placental abruption, but material property of human placenta tissue is not well understood

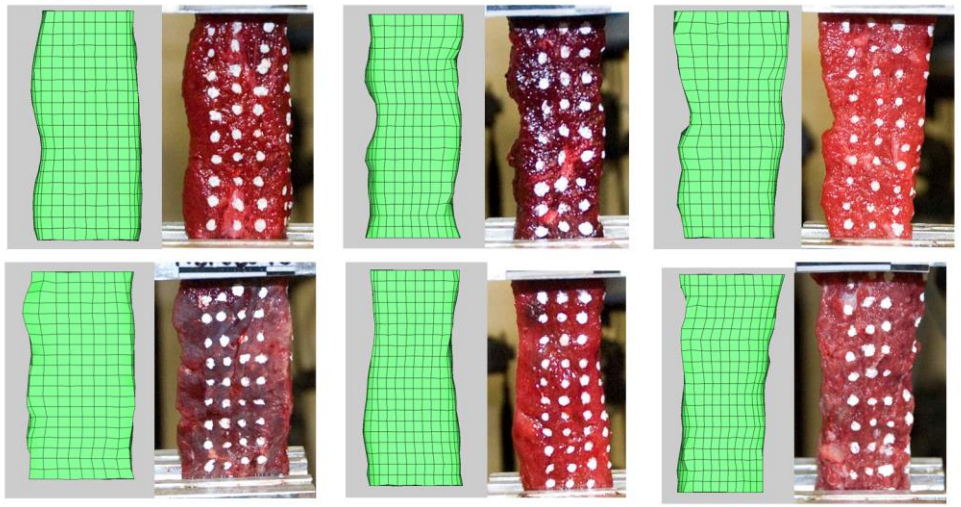
Method: FE + Optimization

Step 1: Build Specimen-specific FE model (46 of them!)

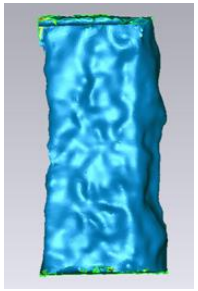
Step 2: Conduct deterministic optimization to find the mean material properties of digital placenta by matching mean test results with simulation

Step 3: Conduct stochastic optimization to determine the standard deviations of previous found optimal material properties (human placentas are different – biological difference!)





Optimization formulation



Hyperelastic (Ogden)

$$W^* = \sum_{i=1}^{3}\sum_{j=1}^{n}\frac{\mu_j}{\alpha_j}\left(\lambda_i^{*\alpha_j} - 1\right) + \frac{1}{2}K(J-1)^2$$

Design Variables

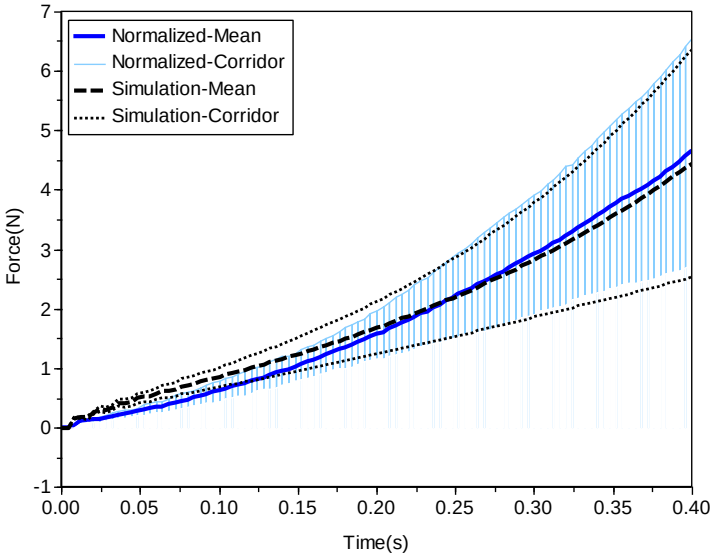
Viscoelastic

$$\sigma_{ij} = \int_0^t g_{ijkl}(t-\tau)\frac{\partial \varepsilon_{kl}}{\partial \tau}d\tau \qquad g(t) = \sum_{i=1}^{n} G_i e^{-\beta_i t}$$

	Optimization 1: deterministic	Optimization 2: Stochastic
Design Variables	*μ_1, α_1, G_1, β_1 and damping*	Standard Deviation (SD) of optimial *μ_1, α_1, G_1, and β_1*
Objective	*Sum-of-Square error of average force curves at 3 strain rates*	*Sum-of-Square error of force SD curves at 3 strain rates*
Optimizer	*non-dominated sorting GA*	*non-dominated sorting GA*
Sampling method	*n/a*	*Latin Hypercube Sampling, 40 design samples for each nominal design*

Optimization Results

Design variables	Optimal mean	Optimal Standard Deviation
μ_1	2.787 kPa	0.403 kPa
α_1	6.929	1.051
G_1	21.505 kPa	3.319 kPa
β_1	0.051 /ms	0.009 /ms



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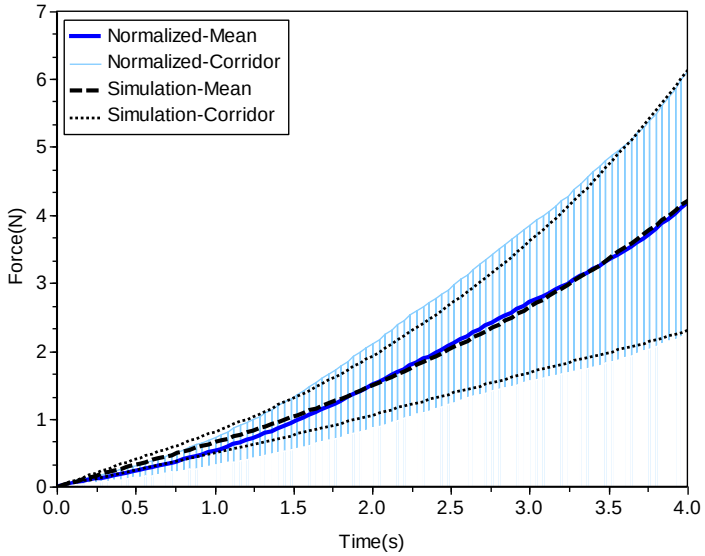

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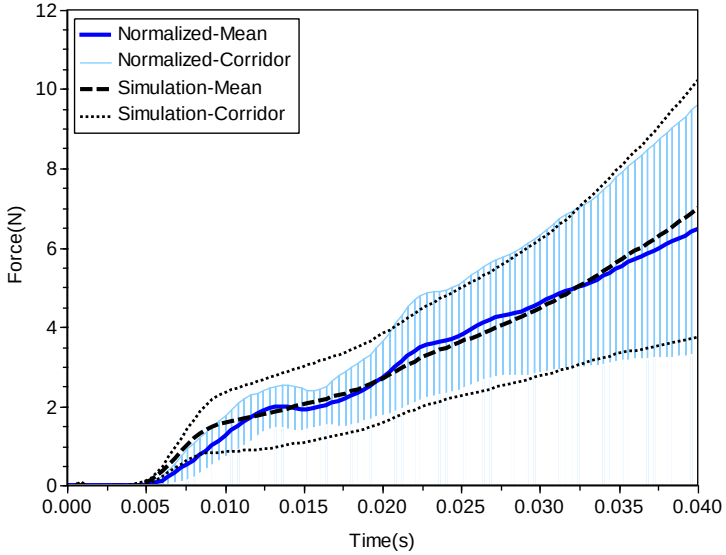


12/s

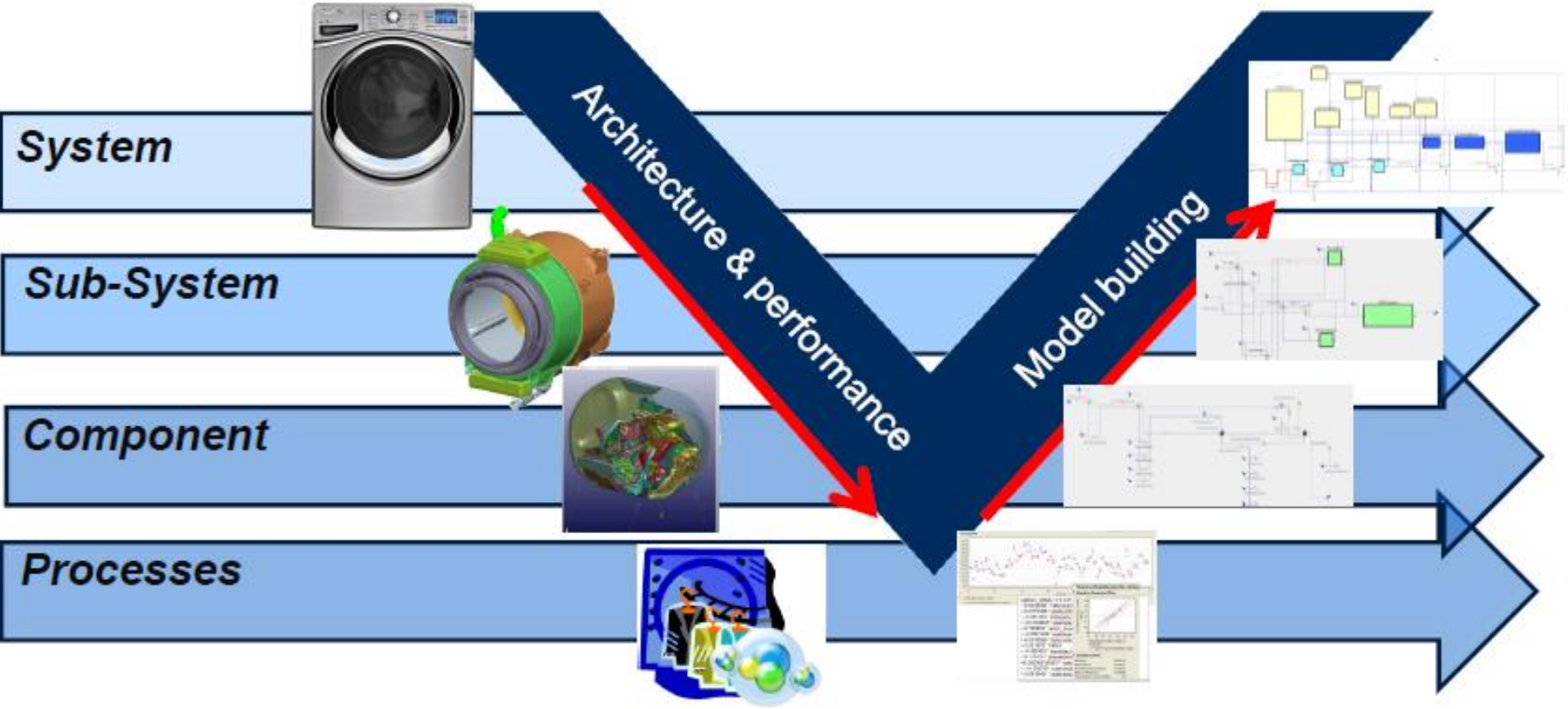
What does this application tell us?

- “Reverse engineering” human placenta tissues with biological difference – using optimization is the only way!

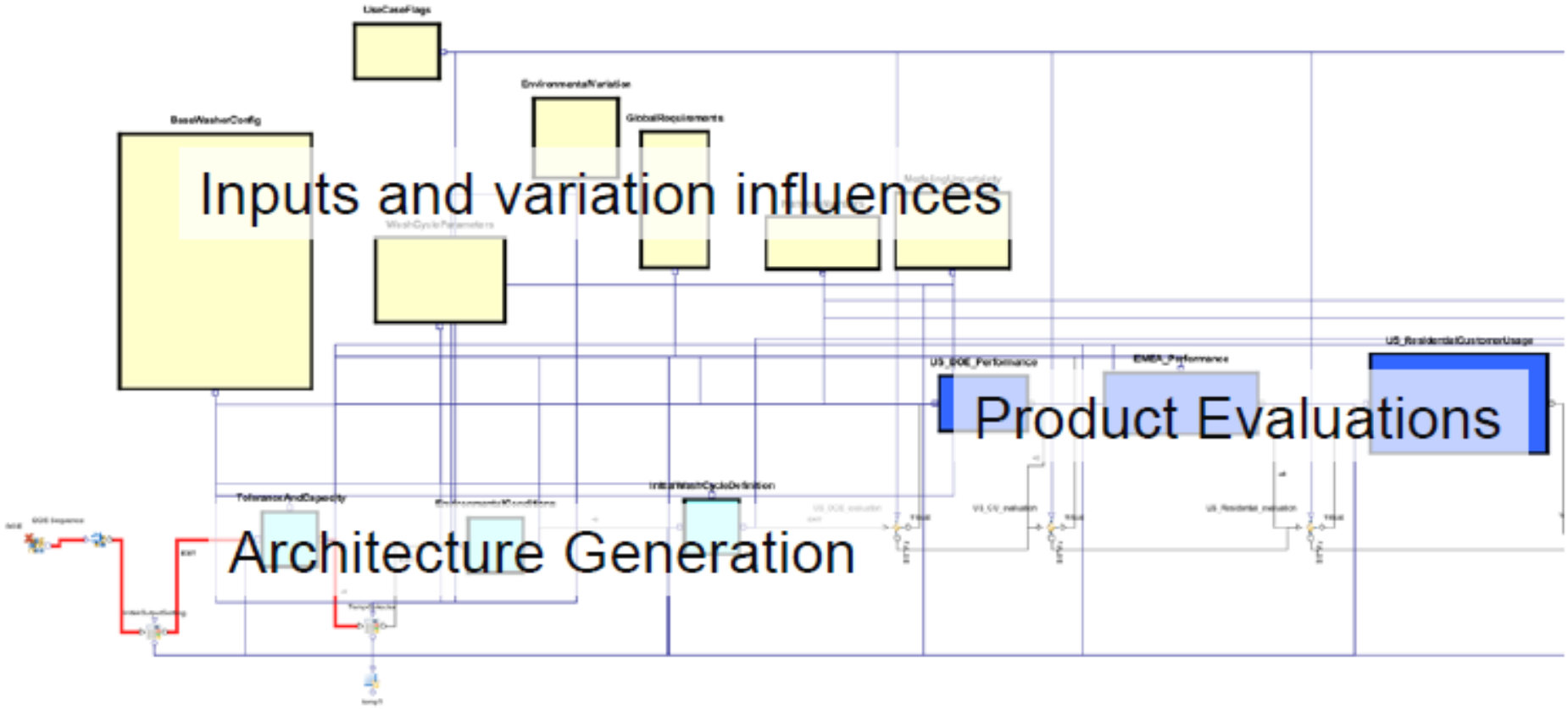
Application 3: Attribute Modeling and System Level Performance Optimization for Household Appliances

Greg Garstecki, G., Attribute Modeling and System Level Performance Optimization for Household Appliances, presented on Esteco North America UM 2013

Modeling System Level Performance



High level view of the Fabric Care System Model

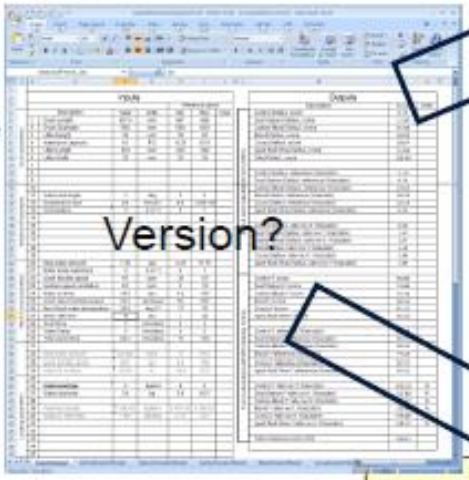


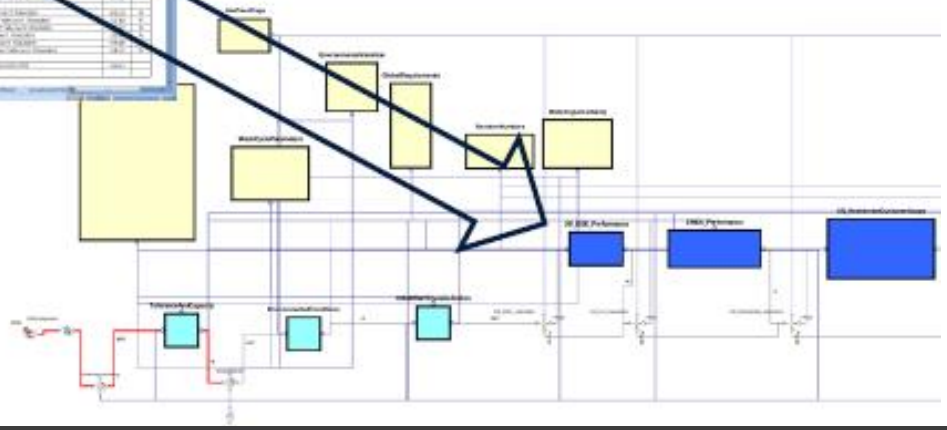
System Model couples Attributes and Architecture performance together so that interactions and influences are readily seen

Modeling Performance of Attributes

Physics based
Predictive (RSM)
Models

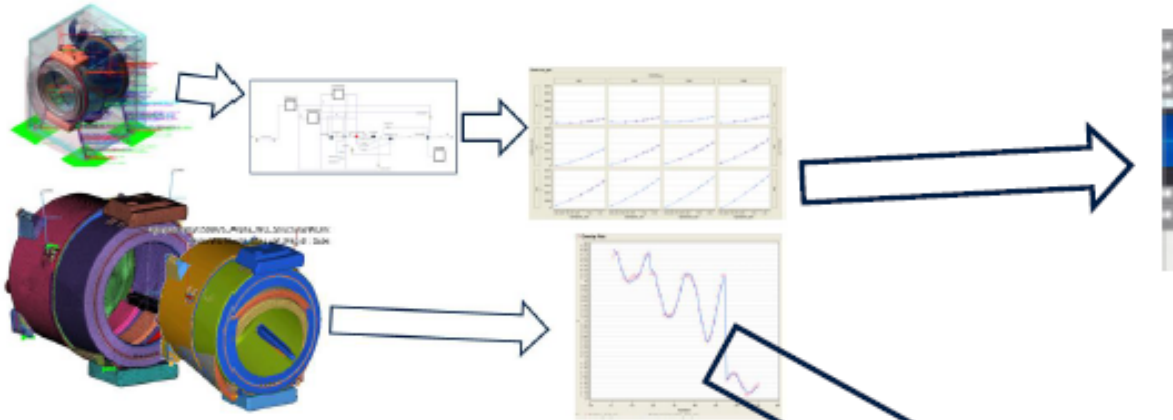
Use models before testing





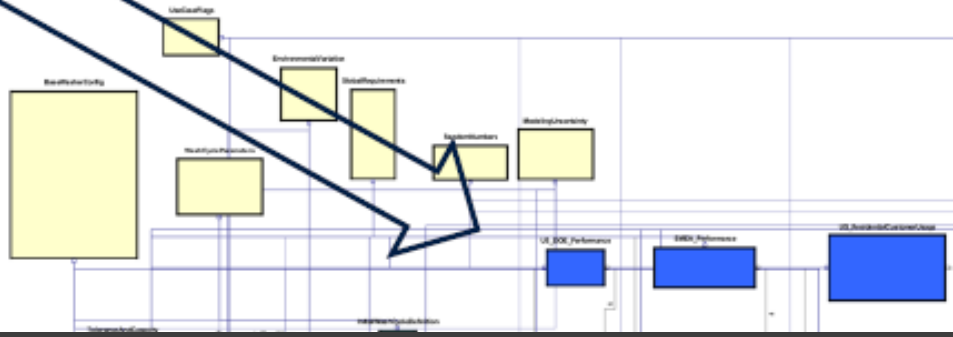
The Attribute models are generated in a way that they can be integrated into the modeFRONTIER full system flow AND can be re-used within the engineering community

Modeling performance of subsystems



Evaluating manufacturing capability

RSM Model for each architecture sets



Problems:

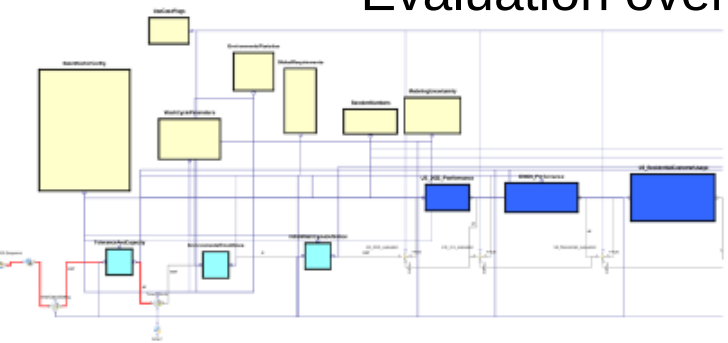
- CAE models have the accuracy of high fidelity simulation models without the calculation speed needed for System Level evaluations
- Cannot co-simulate these within the system level assessments

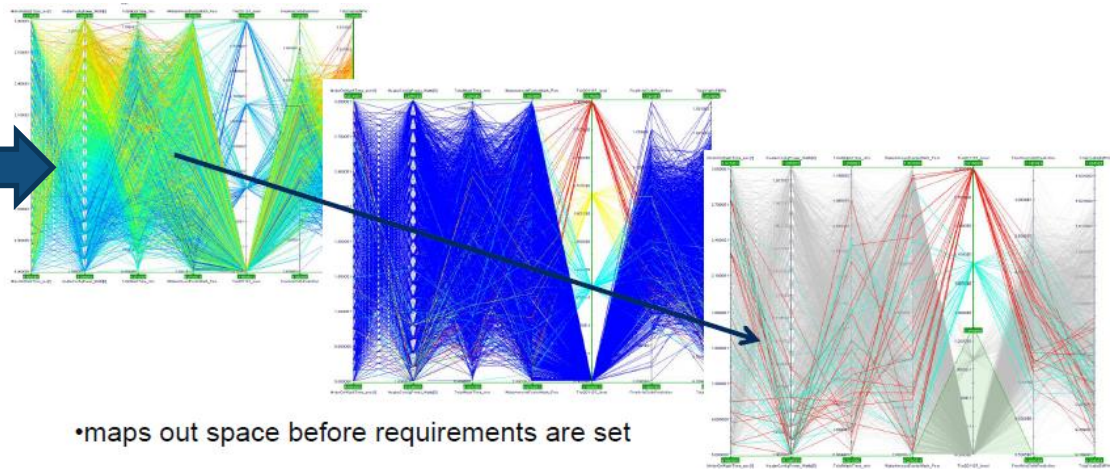
Solution:

- “DOE + RSM” to generate response surface output structure that can be reused in system level and leveraged by other engineers

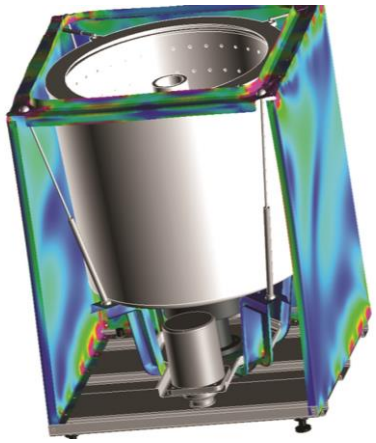
System level evaluation and optimization

Evaluation over different architecture sets

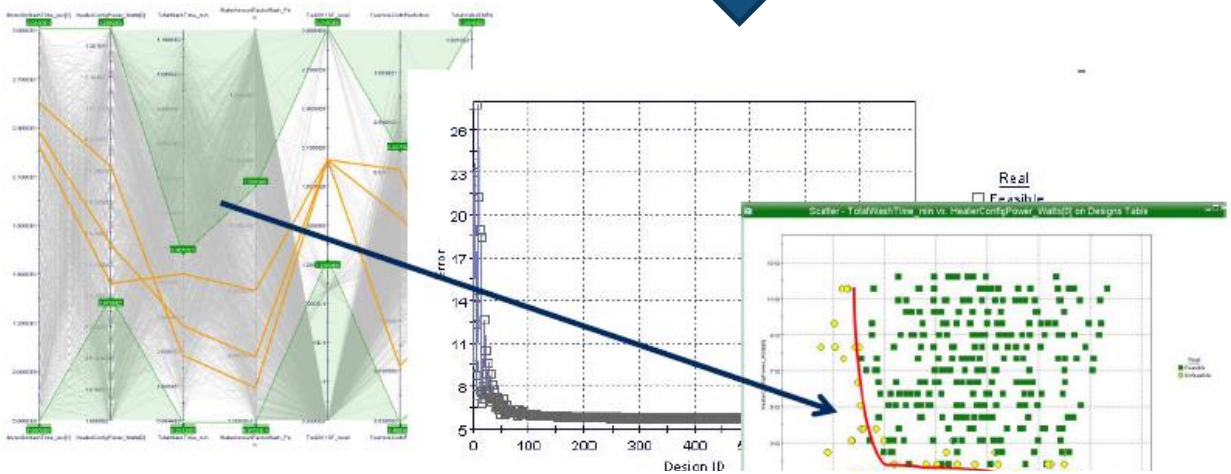




•maps out space before requirements are set



CAE and Test Validation



Conduct Multi-objective optimization to determine architecture set and cycle design that deliver all requirements

What does this application tell us?

- modeFRONTIER enables the system level modeling and optimization

- A successful MDO example for the entire product
  - Think from System level to component level
  - Act from component level to system level

- Mighty power of Response Surface Modelling (RSM)

Go Further

Application 4: Development and Applications of Enterprise Multi-disciplinary Design Optimization (EMDO) Systems

Yan, F., Development and Applications of Enterprise Multi-disciplinary Design Optimization (EMDO) Systems, presented on Esteco North America's user meeting on Nov 04, 2015

Motivation and Objectives

Internet/Mobile Revolution is the Key Enabler for EMDO

- ✓Develop a 24/7 web based service-oriented architecture
- ✓Develop high performance computing (HPC) management
- ✓Develop database architecture
- ✓Develop flexible/efficient EMDO strategies, methods, and processes
- ✓Benchmark EMDO using large-scale vehicle design applications

Complexity of Vehicle Design

Vehicle Performance

V: Vehicle Level
S: System Level
C: Component Level

Vehicle NVH

- Idle Tactile (V)
- Idle Acoustic (V)
- Driveline Unbalance Tactile (V)
- Driveline Unbalance Sound (V)
- Glen Eagle Tactile (V)
- Rough Road Tactile (V)
- Brake Roughness Tactile
- Impact Harshness Tactile
- R1H / CP2 Tactile (V)
- Glen Eagle Acoustic (V)
- Rough Road Acoustic (V)
- Impact Harshness Acoustic (V)
- Brake Squeal
- Exhaust NVH
- Wind Noise
- Shift Quality
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Safety

- FRONT IMPACT (V)
- New FMVSS 208
- NCAP
- OOP
- IIHS Offset
- SIDE IMPACT (V)
- 33.5 mph FMVSS214
- LINCAP
- Rear Impact (V)
- 35 mph RMB
- 50 mph C/C Inline
- 50 mph C/C Side
- 50 mph C/C 50% Offset
- Roof Crash (S)
- Head Impact (S)
-
-
-

Body Structure (NVH & Durability)

- Trimmed Body Principal Modes (V)
- Trimmed Body Static Stiffness (V)
- BIP Principal Modes (S)
- PM at Body Attach. Loc.(S)
- LP6 for Body Attachments (S)
- Static Stiffness for Body
- Attachment Locations (S)
- Body SDS/WCR/FMVSS (S/C)
- Hood (S)
- Decklid (S)
- Doors (S)
- Trailer Tow (C)
- Dash/Cowl fatigue (C)
-
-

Chassis & Full Vehicle Durability

- Chassis NVH
  - Frame Principal Modes
  - Frame Static Stiffness
  - Static Stiff. at Frame Attach.
  - PM at Frame Attachments
  - Suspension Modes
- Chassis Durability
  - Front Suspension
  - Rear Suspension
  - Frame and Mounting System
-
-
-
-
-
-

Vehicle Dynamics

- Vehicle Dynamics (V)
  - Steering
  - Handling
  - Ride
  - Braking
- Chassis Systems (S)
  - General Vehicle
  - Front Suspension
  - Rear Suspension
  - Steering
-
-
-
-
-

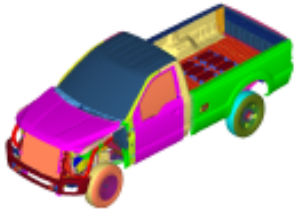
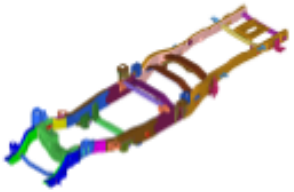
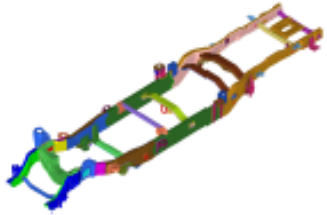
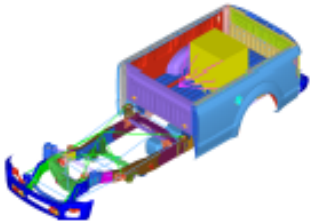
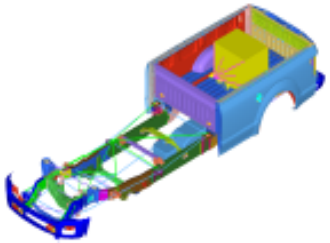
TASE* & Climate Control

- Aerodynamics CFD Analysis (V)
- Heat Management (V)
- Coolant Flow Simulations (S)
- Vehicle Level Climate Control (V)
  - Front End Air Flow
  - Front End Openings
- System Level Climate Control (S)
  - A/C Performance
  - Heater Performance
-
-
-
-
-

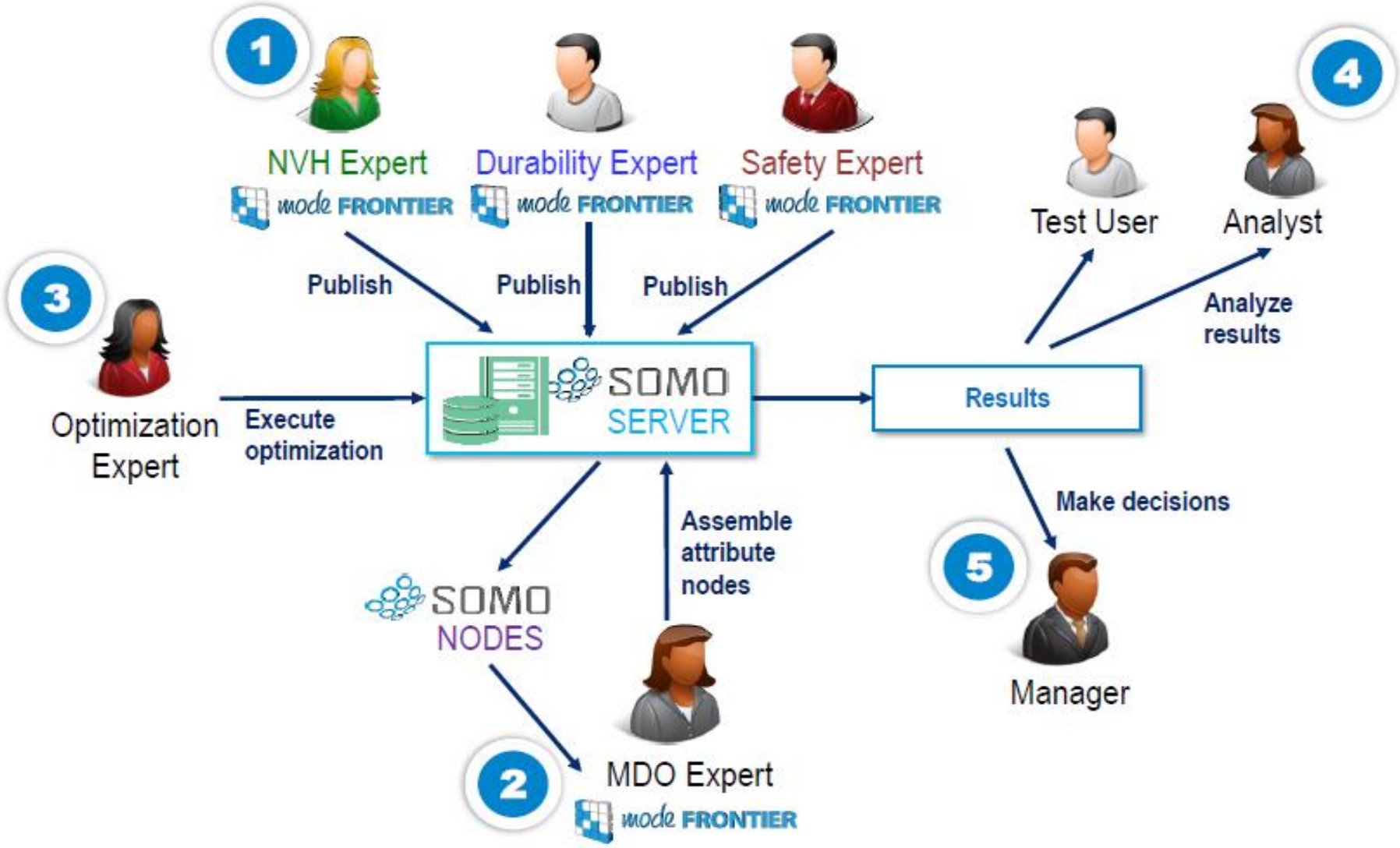
*TASE: Thermal Aerodynamics System Engineering

A Vehicle Weight Reduction MDO Problem

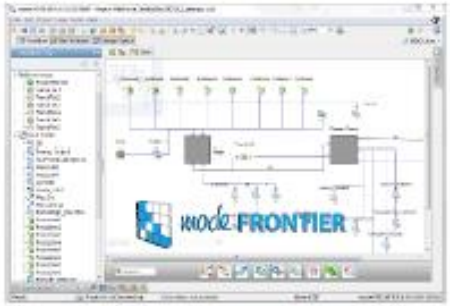
- Design Objective: Minimize Weight
- Constraints: Safety, NVH, Durability
- Total Design Variables: 113
- Responses: 34

	4x2 142”	4x4 142”	4x4 176”	Computation Cost
NCAP: VPI &				3 hours (32 CPU)
NVH: Modes				0.05 hours (4 CPU)
Durability: Stresses				0.2 hours (2 CPU)

MDO By Using modeFRONTIER and SOMO (now Volta): Use Scenario

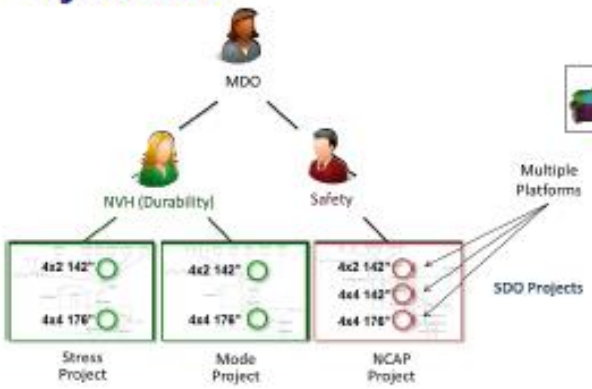


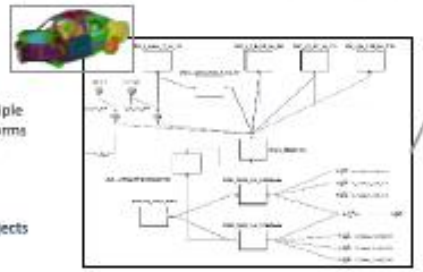
MDO By Using modeFRONTIER and Volta: Procedures

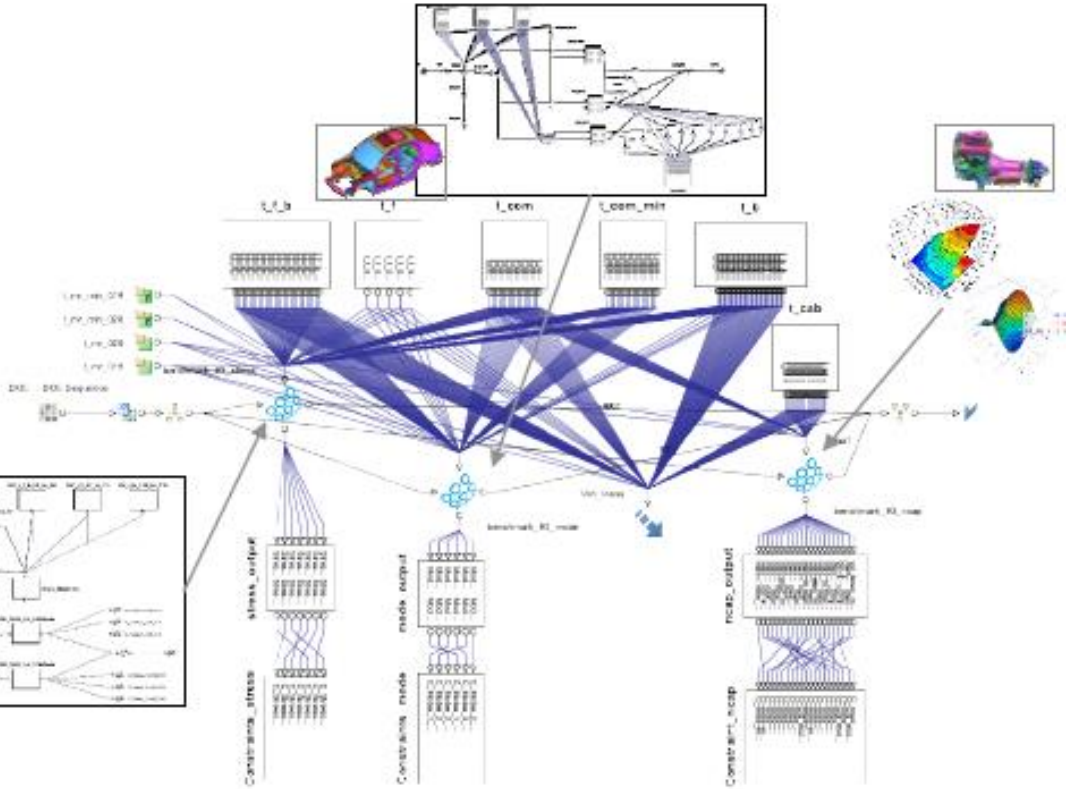


MDO COLLABORATION

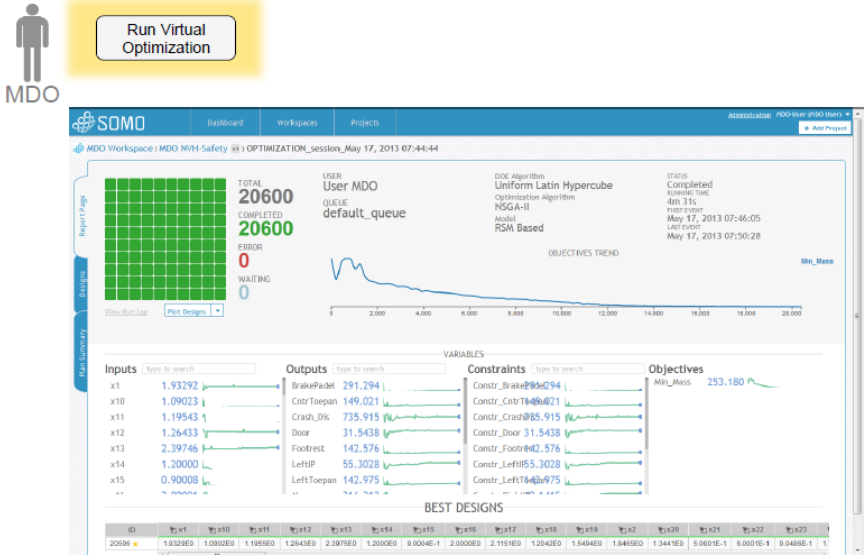
- ✓ **Compose** versioned processes from different **domains** and **Systems**

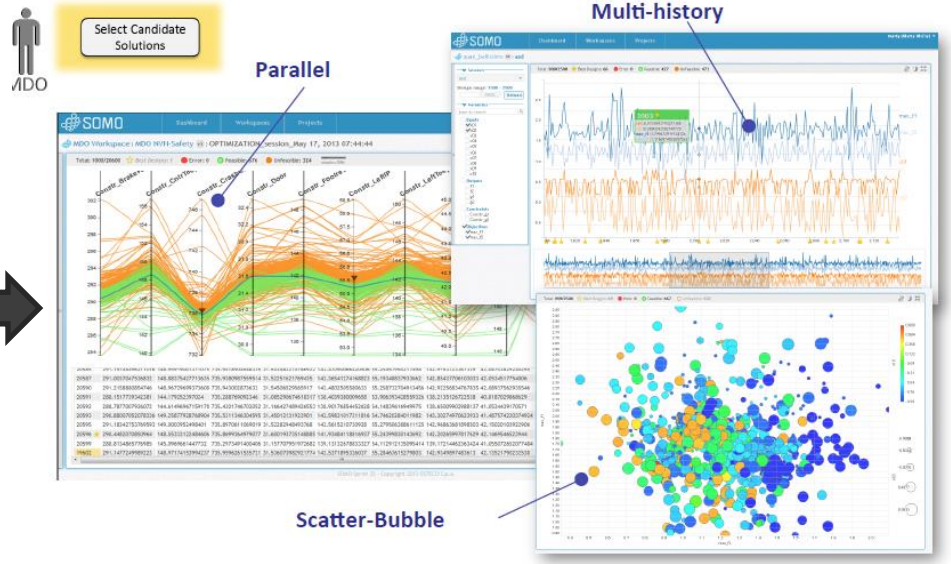




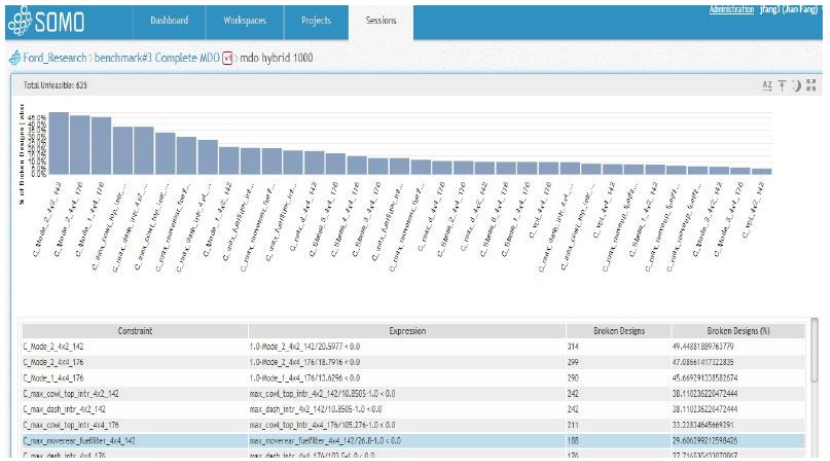


MDO By Using modeFRONTIER and Volta: Run and Analyze





	Baseline Design	Optimal Design
Mass	653.6	644.7
C_Mode_2_4x2_142	4.219E-4	-8.301E-5
C_Mode_2_4x4_176	2.890E-4	-4.098E-5
C_Mode_1_4x4_176	2.861E-5	-3.507E-5



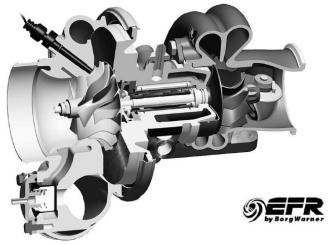
MDO By Using modeFRONTIER and Volta: Summary of Benefits

- For the Company
  - Simplified, multi-user repeatable design process
  - Collaboration between teams and organizations
  - Common Repository for sharing knowledge and best practices
  - Compliance with security and data privacy policies

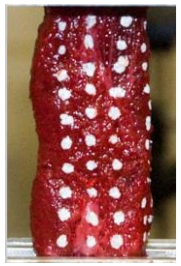
- For Engineers
  - Better organized and more efficient environment for simulation and optimization
  - Trace results to models and simulation parameters

- For Managers
  - Easier and simpler access to results
  - More informed and faster decision making

So, using modeFRONTIER and Volta:



- ✓ Product design just getting better and better



- ✓ Perhaps no other alternatives

- ✓ mF enables System level MDO

- ✓ mF + Volta: From single expert, to team, to organization

Looking into the Future – from our customers

- "Craw, walk run" approach - especially with optimization
  - Regular user of mF for serveral years
    - Focus has been on structural analysis
    - Internal discussions for CFD, controls, etc. with goal of multiphysics
  - Benchmarked Whirlpool in 2015, decided for Capable/STANDARD tools – modeFRONTIER is preferred
  - Analysis Led Design using modeFRONTIER and Volta brings cross-organization cultural change

Go Further

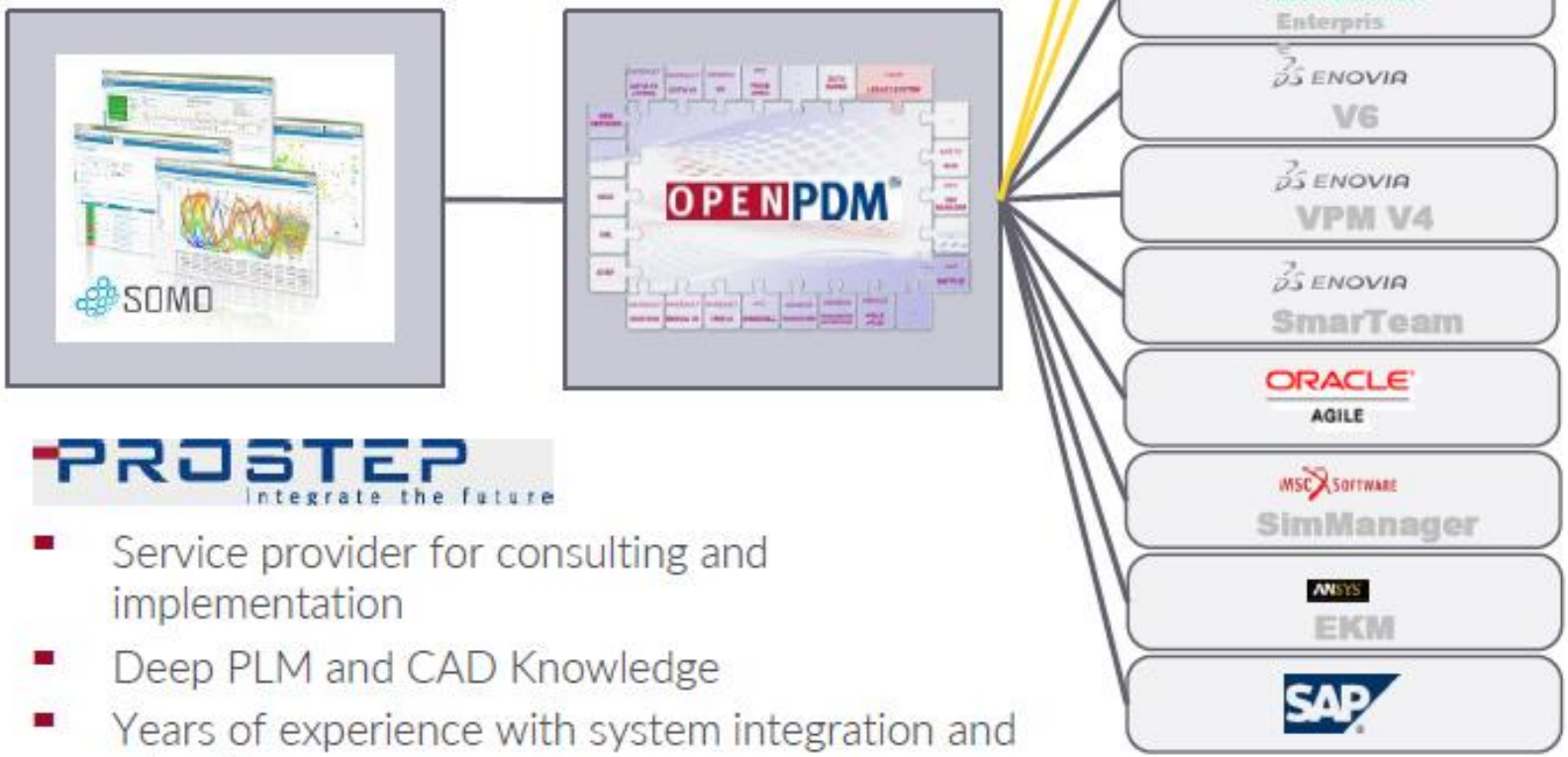
- Lead/champion users of modeFRONTIER promote the use of modefrontier throughout the organization
- Use VOLTA as a knowledge repository to help educate young engineers

Tickel, B., Analysis Led Design at Cummins, presented on Esteco's user meeting 2016

Looking into the Future with Volta – from ourselves

OpenPDM®

Universal SOMO integration solution for other systems PDM/PLM and CAD data access



PROSTEP integrate the future

- Service provider for consulting and implementation
- Deep PLM and CAD Knowledge
- Years of experience with system integration and migration

Nicolich, M., ESTECO Enterprise Suite and SOMO Product update, presented on UM 2016 at Trieste, Italy

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咨询邮箱：marketing@idaj.cn

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