Design for real
Optimus®

MDO Methods and Tools

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Noesis Solutions

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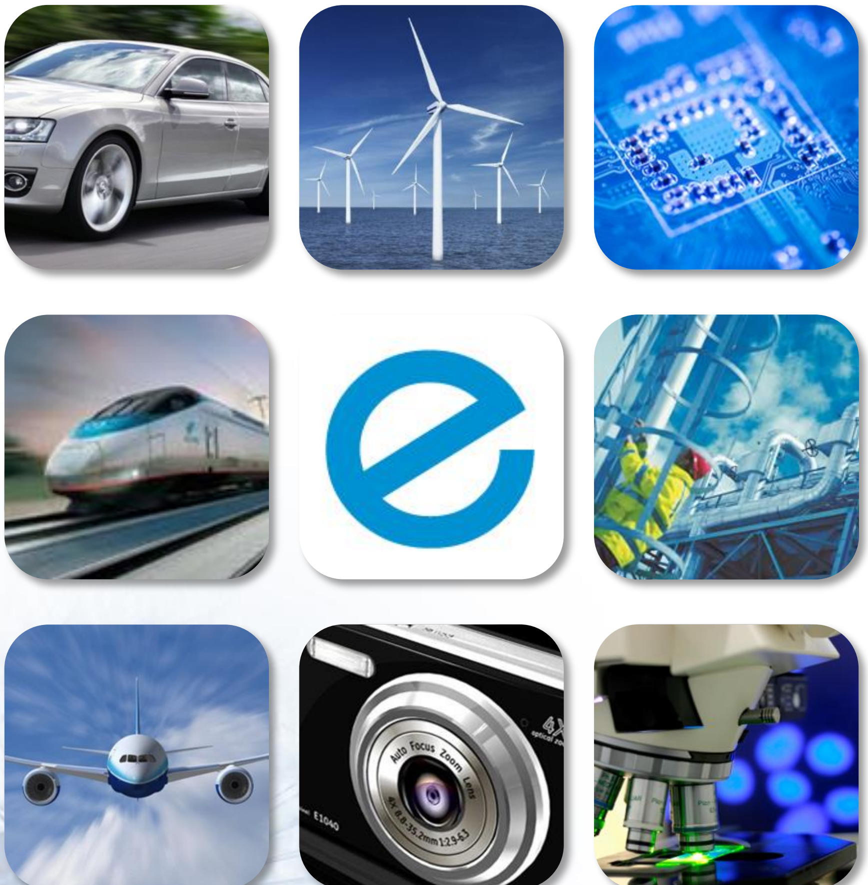
Empower your experience

Outline

- Introduction about Noesis
- MDO Tools and methods: context & challenges
- High dimensional MDO
- Electrical Wire Harness case
- Conclusions

Noesis Solutions

who we are



Noesis Solutions is an engineering innovation partner to manufacturers in engineering-intense industries.

We are specialized in simulation process integration & numerical optimization

and help our customers resolve their toughest multi-disciplinary engineering challenges.

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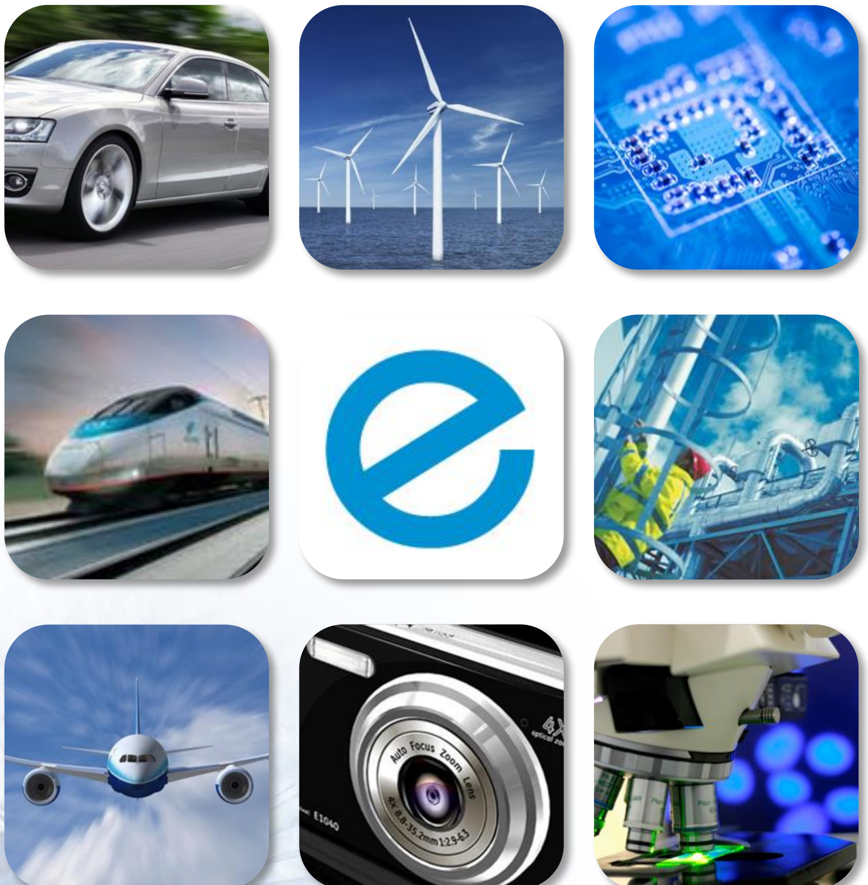
what we do: Optimus



Our Optimus software platform enables customers to adopt an “Engineer by Objective” development strategy.

It automates ‘trial-and-error’ simulation based design processes

and directs simulation campaigns toward the best product designs.

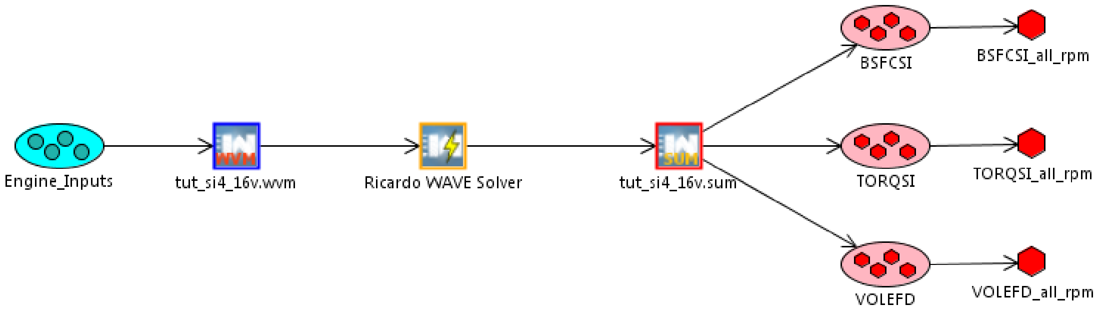
Optimus by Noesis Solutions

The leading vendor-neutral solution for engineering optimization

Process Optimization

- create automated, repeatable simulation processes
- integrate in-house tools & methods
- capture simulation knowledge
- custom applications

FASTER



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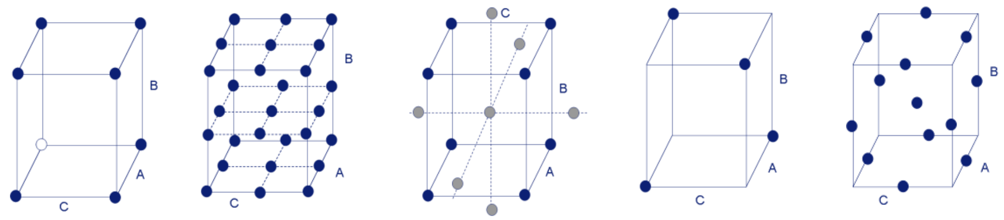
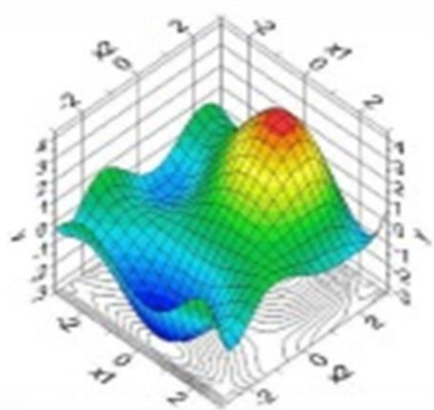
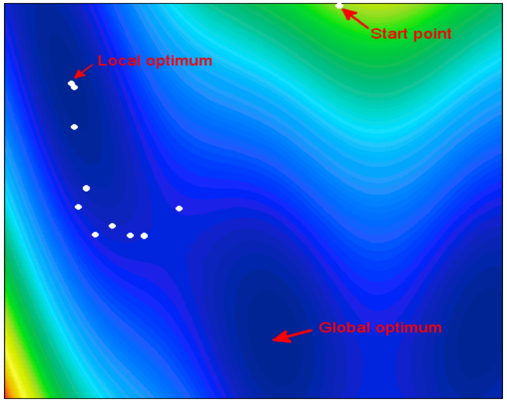
Design Optimization

- identify influental design parameters
- gain critical engineering insights, enabling smarter decisions
- eliminate non-feasible designs, identify leading design candidates

BETTER







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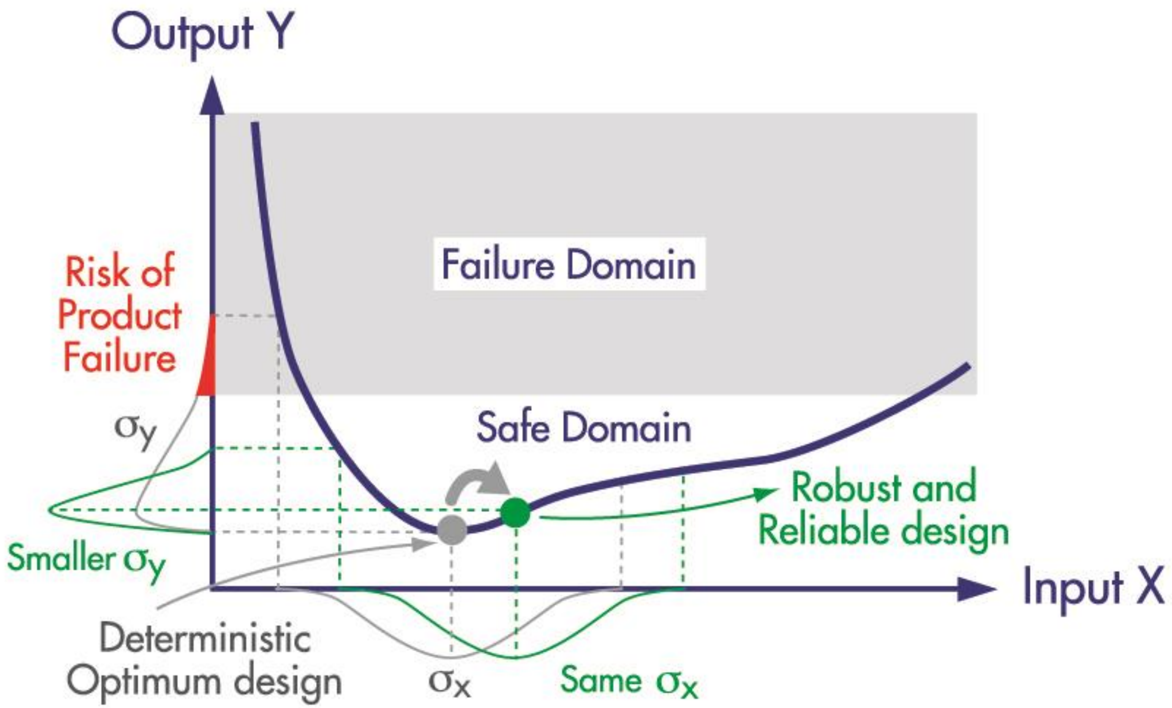
Robust Optimization

- develop robust & reliable products
- ensure consistent product quality throughout product lifecycle



MORE RELIABLE

Open environment

with Python scripting

python™

Automating in-house processes	Crafting dedicated applications	Capturing corporate knowledge

Automating in-house processes

- Facilitate stress analysis
- Automate stress Report
- Formalize Simulation Process
- Reduce Human Involvement

Crafting dedicated applications

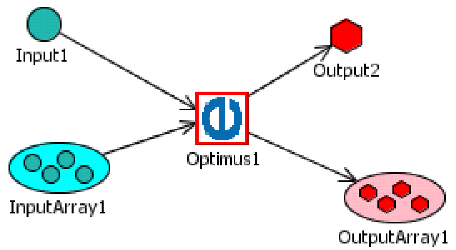
- Improve Active/Passive Crash
- Select Dominant LC
- Simultaneous Euro / USCAP
- Speed-up Crash Simulation Decision

Capturing corporate knowledge

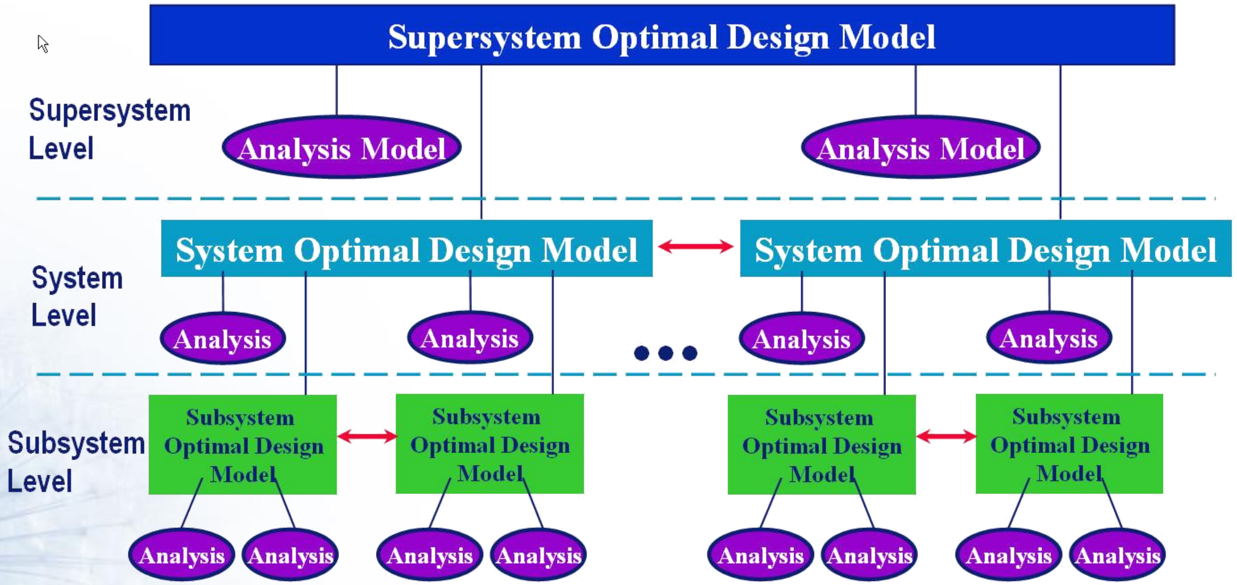
- Support selection of best optimization algorithm
- Build method cartography
- Validate deployment of methods

Open & extendable environment to respond to any custom need

… with a Multi-Level approach



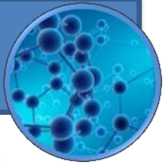
- Multi-Level environment:
  - Drive simulation cascaded process with OPTIMUS
  - Handle Bottom-level workflow with a Top level OPTIMUS
  - Carry Up and Down Inputs/Outputs/Constraints



Research and Innovation

- Multi-disciplinary problems
- Formalize interoperability solutions
- Scalable automation & execution

Solve complexity



Research & Innovation

- Capture and re-use Knowledge
- Modular SW components
- Interoperability: open and extendable

Manage Heterogenei

- Distributed computations
- Virtualization & Cloud computing
- Service Oriented Architectures (SOA)

Execute Efficiently

Outline

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Context

- Complex engineering problems use high fidelity simulation models and expensive experiments
- Ever increasing competition imposes time and budget constraints on the development of new products
- Need to infer maximum amount of information
  - from limited number of simulation runs
  - obtain competitive solutions

Problem

- We never achieve 100 % accurate simulation or experiments
  - if they are high fidelity, they are expensive.
- Problem scale keeps increasing
  - number of design parameters and data size
- Design is progressive
  - The user initially does not know proper parameter bounds, constraints, what to model and what to ignore

What we can trade in for finding an "optimal solution"

- Quantitative accuracy of performance is not always of primary importance but relative merit is
- Very often a "competitive" solution is all we need, not necessarily the best possible solution
  - Especially true if the problem is multi objective or highly constrained (best difficult or expensive to achieve)
  - Overall sound solution important in safety critical applications (best too good to be true)
- The point is to have different shades of optimality

Why accept such relaxation?

- "Best" is capricious
  - Predicting World Cup top 8 teams is easier than predicting the winner.
  - Engineers can usually agree on good designs but may disagree on the "best one".
- "Best" depends
  - We are usually uncertain of what we mean by best.
  - Optimization problem set up is an art, not science.
- "Competitive" is intuitive
  - Humans are good at discerning it
  - We could allow human expertise and past statistical data to take part in the search for solution

Large Scale MDO Challenges

- Large design space to explore involving heavy sampling
- Risk to linearize design space by reducing sampling
- High probability to violate constraints
- Challenge to bound a confidence region that fulfills all constraints AND improves the design
- Access to an adequate environment
  - Visualize the data and rely on metrics to validate the optimum
- Hardware path
  - Increase CPU Services with HPC Cluster
  - Increase RAM to store large matrix
- Simulation Solver Path
  - Enable analytic sensitivities directly in the solver

How to do it?

- Differentiate Dimensional and Domain reductions
- Identify inter-relations and use them
- Methodologies:
  - Graph decomposition
  - Feasible region identification
    - Deep Learning and SOM based adaptive sampling (SOMBAS)
  - Domain shrinkage using Sobol Indices (DSSI)
  - Interaction Indices

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Research and Innovation tracks

Simulation Framework

- Web 2.0 based corporate federation toolkit
- Dynamic multi disciplinary design workflow

Machine Learning

- Knowledge capture and reuse,
- Optimize large, highly dimensional full scale models

Cloud and HPC

- Virtualize execution via cloud computing
- Web Services and access from everywhere

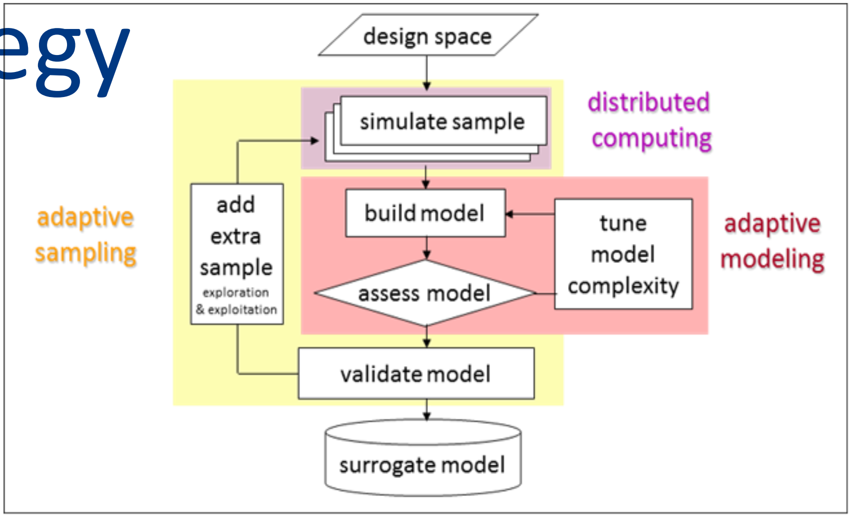
HAROS-HD

- Hybrid Adaptive Robust Optimization Strategy for High Dimensional systems
  - Optimization strategy (opposed to optimization algorithm)

- Main Objectives
  - Provide new optimization techniques suitable for large scale systems with mixed variables
  - Discover problem 'features' and use them for efficient optimization of subsystems

Overview of the strategy

- Multiple steps involved



Problem decomposition

Dimensionality reduction

Feasible region identification

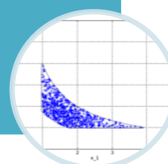
Sub-system optimization

Tuning

Main stream technologies

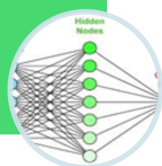
- Non-convex space density learning
- Unsupervised feasible region identification
- Initial space indifferently in feasible/unfeasible solution space

Find feasible solution space



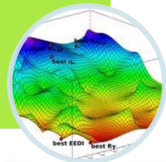
- Adaptive learning sampling
- Identify design space features (ex: search of non-linearities)
- Improve accuracy in optima surrounding
- Mixed variable algorithms (HAROS-HD)

Machine learning: Sampling/optimization



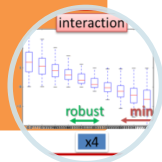
- Aggregate meta models based on confidence maps
- Estimate confidence maps with Neighborhood identification
- Learning profiles to model non-linearities, minima/maxima, etc

Machine learning: Ensemble modeling



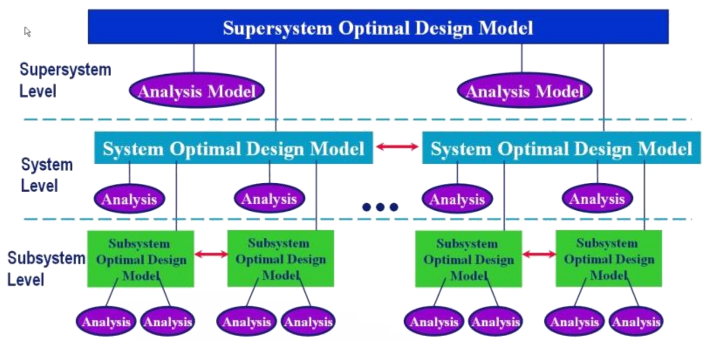
- Decompose large problem in smaller and spot robust solution
- Use interaction & Sobol indices
- Measure degree of interaction between parameters
- Detect parameters independence

Dimension reduction

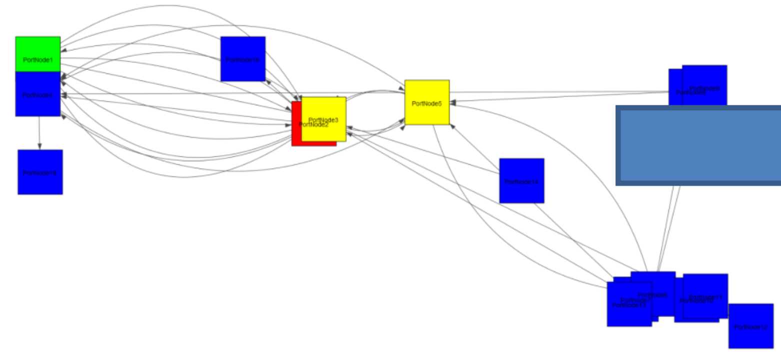


MD Dimension reduction approach

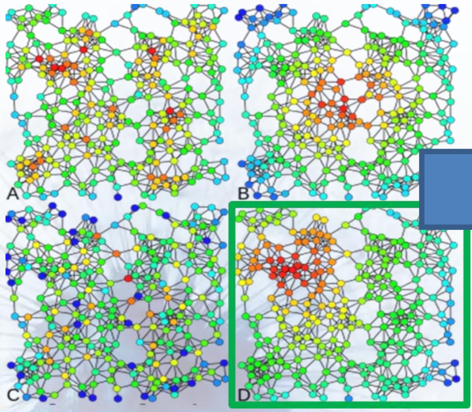
MDO problem formulation



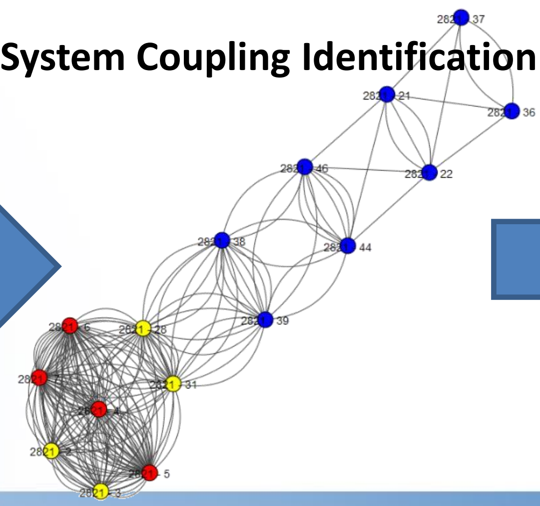
MDO Graph representation



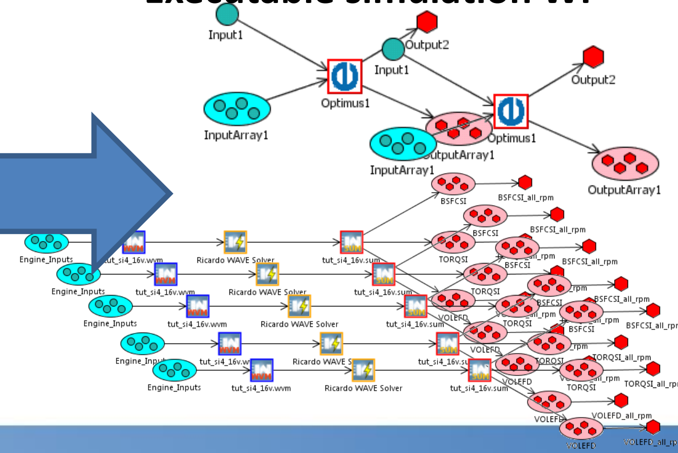
Centrality Analysis



System Coupling Identification



Executable simulation WF



Advantages

- General: can be applied to all optimization problems
  - HAROS-HD will learn about the design space and employ the appropriate algorithms as it proceeds toward finding an optimized solution
- Flexible:
  - HAROS-HD will intelligently adapt the optimization strategy by selecting the most appropriate method to use
- Scalable:
  - It can be used for high dimensional problems

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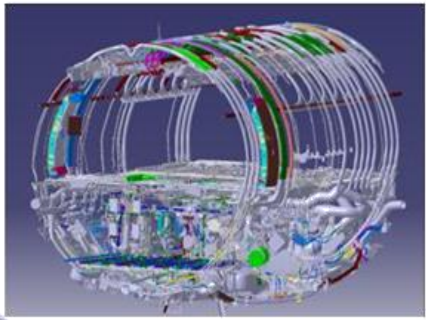
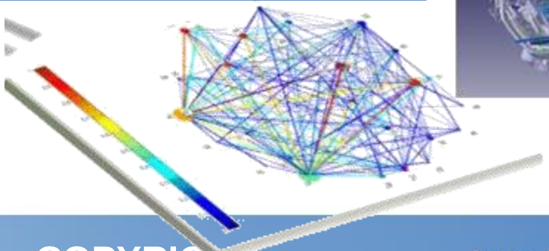
Context

$>10^3$ Wire harnesses	$>10^5$ Electrical links	$>2*10^3$ Kg of electrical installation	$>4*10^4$ Pathway segments
$>10^4$ Connectors	$>3*10^4$ Installation interfaces	$>1.5*10^5$ Meters of cable	$>1.5*10^5$ Signals

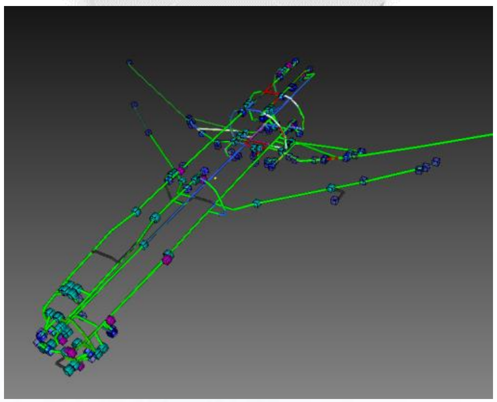
Typical single aisle

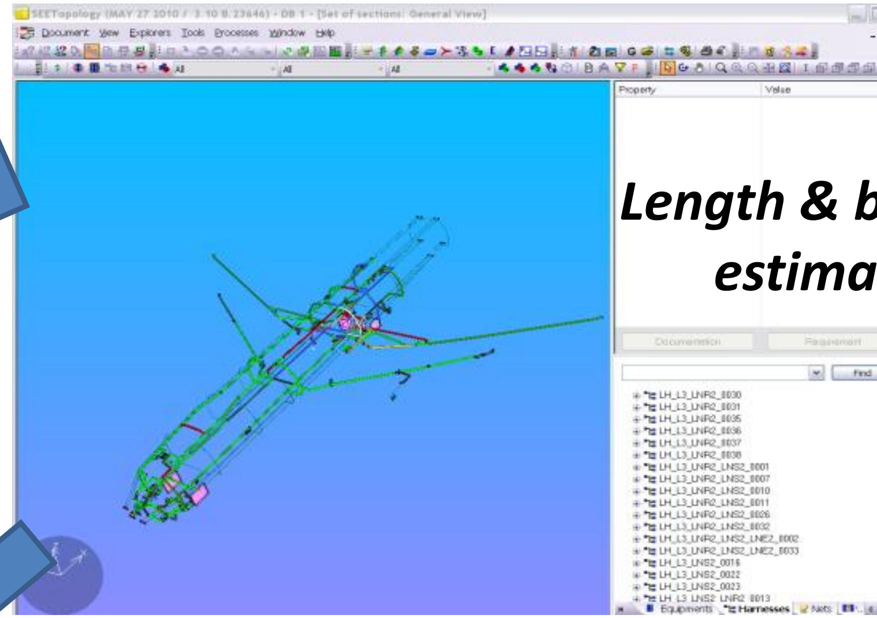




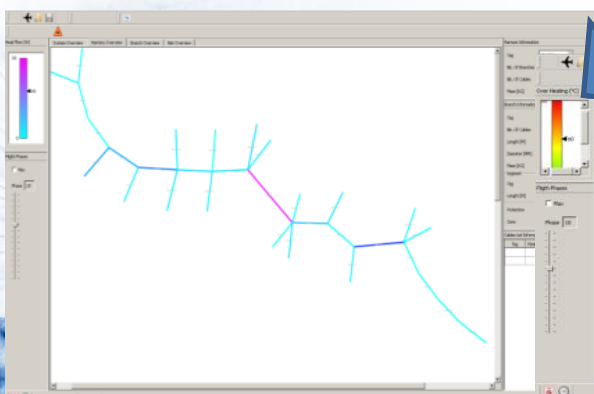
Wire design

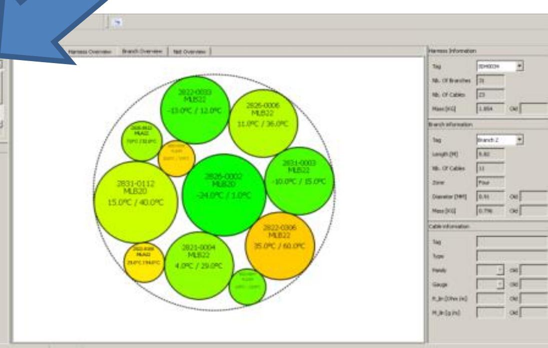
ROUTING SYSTEMS
In the space reservation
Respecting safety & segregation rules





Length & bundling estimation

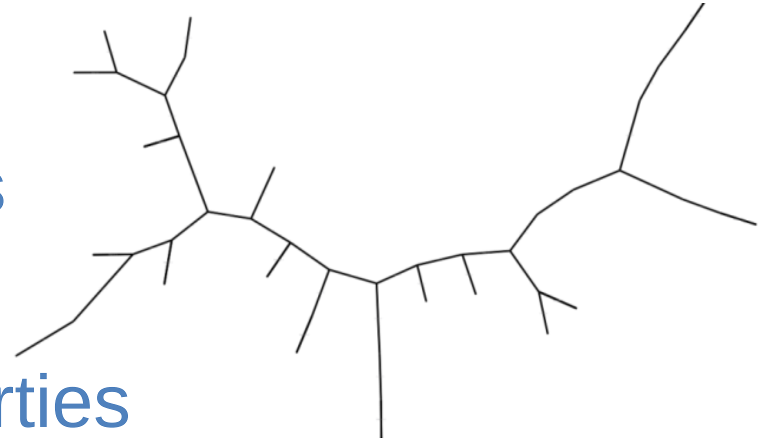


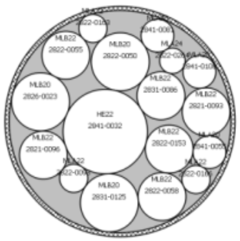


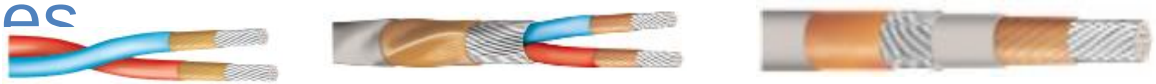
Cable sizing

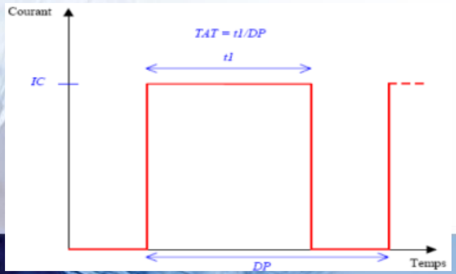
Constraints / parameters

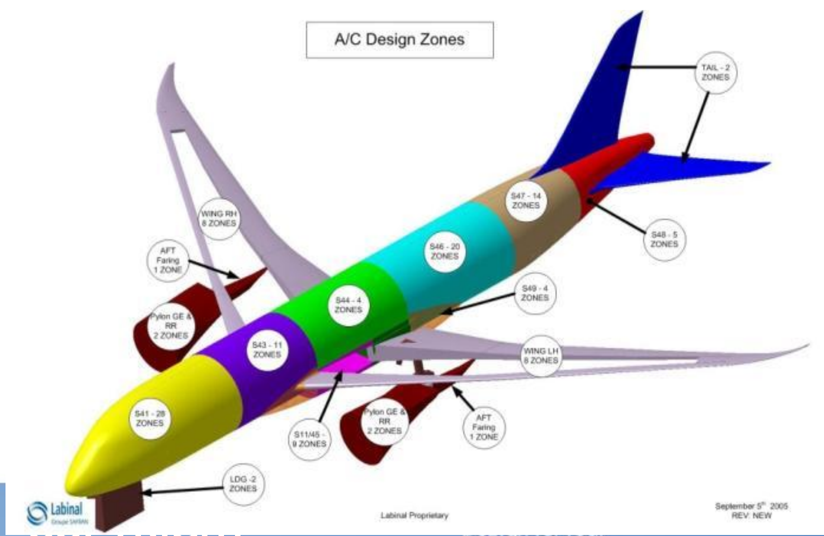
- Harness topology
- Harness protections
- Cable properties
- Electrical link properties
- Aircraft flight phases
- Aircraft areas
- Environmental parameters





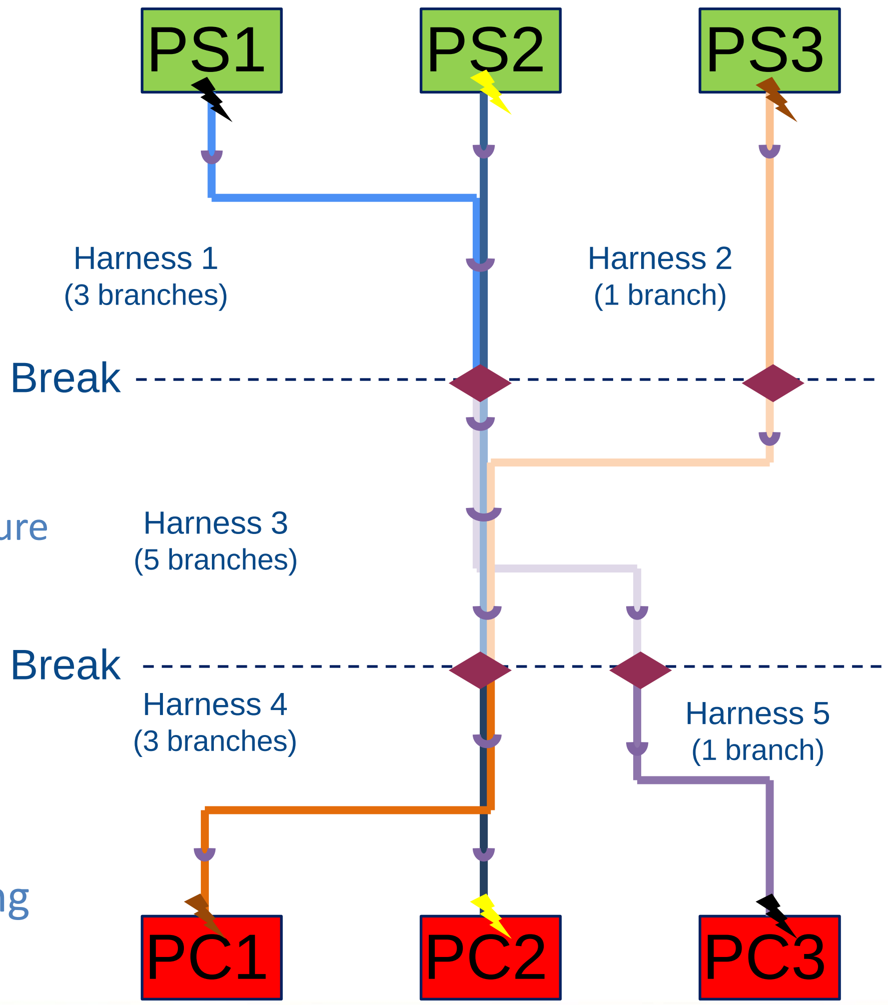






A typical industrial case

- **Wire gauge optimization**
- Cable design
  - Mechanical design
    - Tensile strength
  - Electrical design
    - Maximum voltage drop
  - Thermal design
    - Maximum overheating & temperature
- Problem definition
  - Harnesses interactions
    - Voltage drop computation
  - Cables interactions
    - Overheating computation
  - Voltage drop depends of overheating
  - Discrete problem



Optimization challenges

- Cable gauges optimization problem
- Large scale system
  - Up to 1000 wire harnesses
  - ~10000 cables - optimization parameters
  - ~40000 harnesses branches - thermal constraints
  - ~10000 electrical links – voltage drop constraints
  - Discrete problem (categorical)

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Conclusions

- Complexity and heterogeneity challenges need to be addressed in MDO
- High dimensional systems soon become common
- New methods and tools exist to develop new optimization strategies for large systems
  - Paradigm shift in classical design optimization approaches

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Thank you!

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