Analysis Led Design via Optimization

Kevin Brittain - MDO Group Lead

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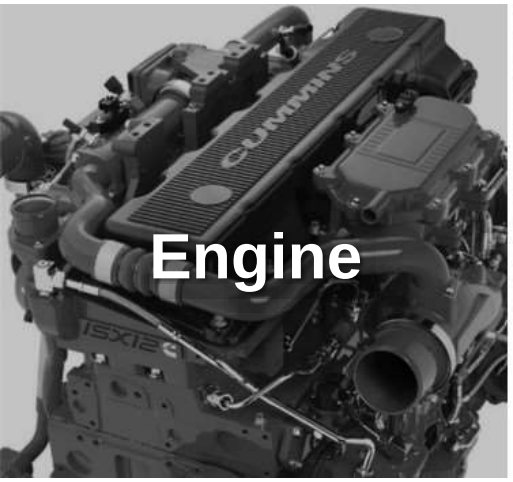
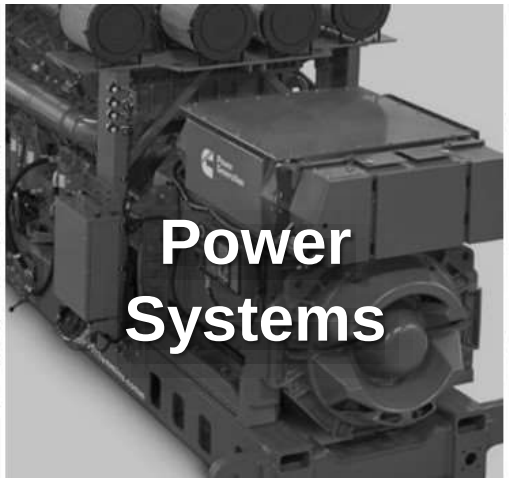
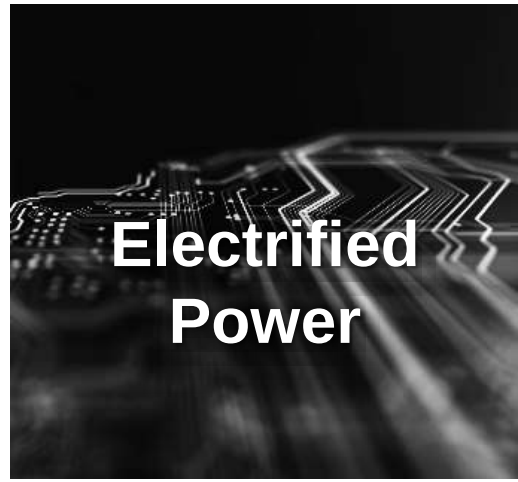
Cummins – Five operating segments

Cummins has a nearly 100-year-long track record of delivering leading power solutions. As we look ahead, we know our industries and markets will continue to change, and we are committed to bringing our customers the right technology at the right time.







Cummins powering a more prosperous world

190
Countries & territories

58,600
Global employees

1.3M+
Engines built in 2017

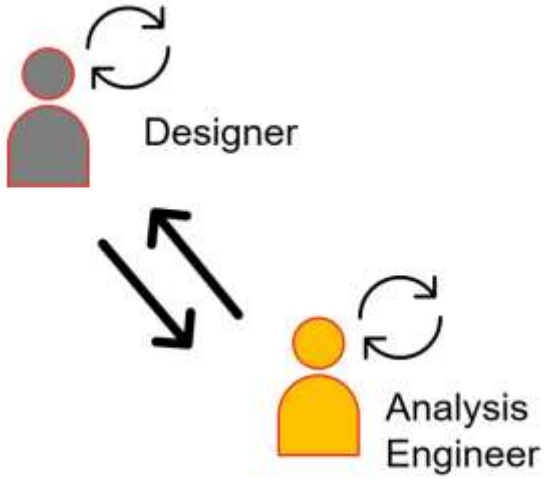
8,000
Wholly-owned & independent distributor & dealer locations

$734M
Invested in research & development in 2017

99
Years of industry leadership

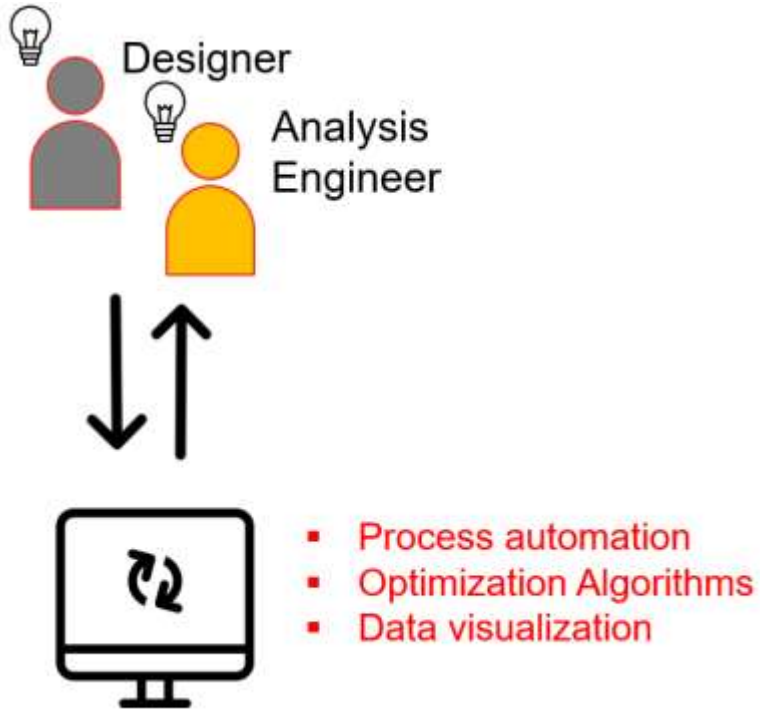
The History of ALD (Analysis Led Design)…

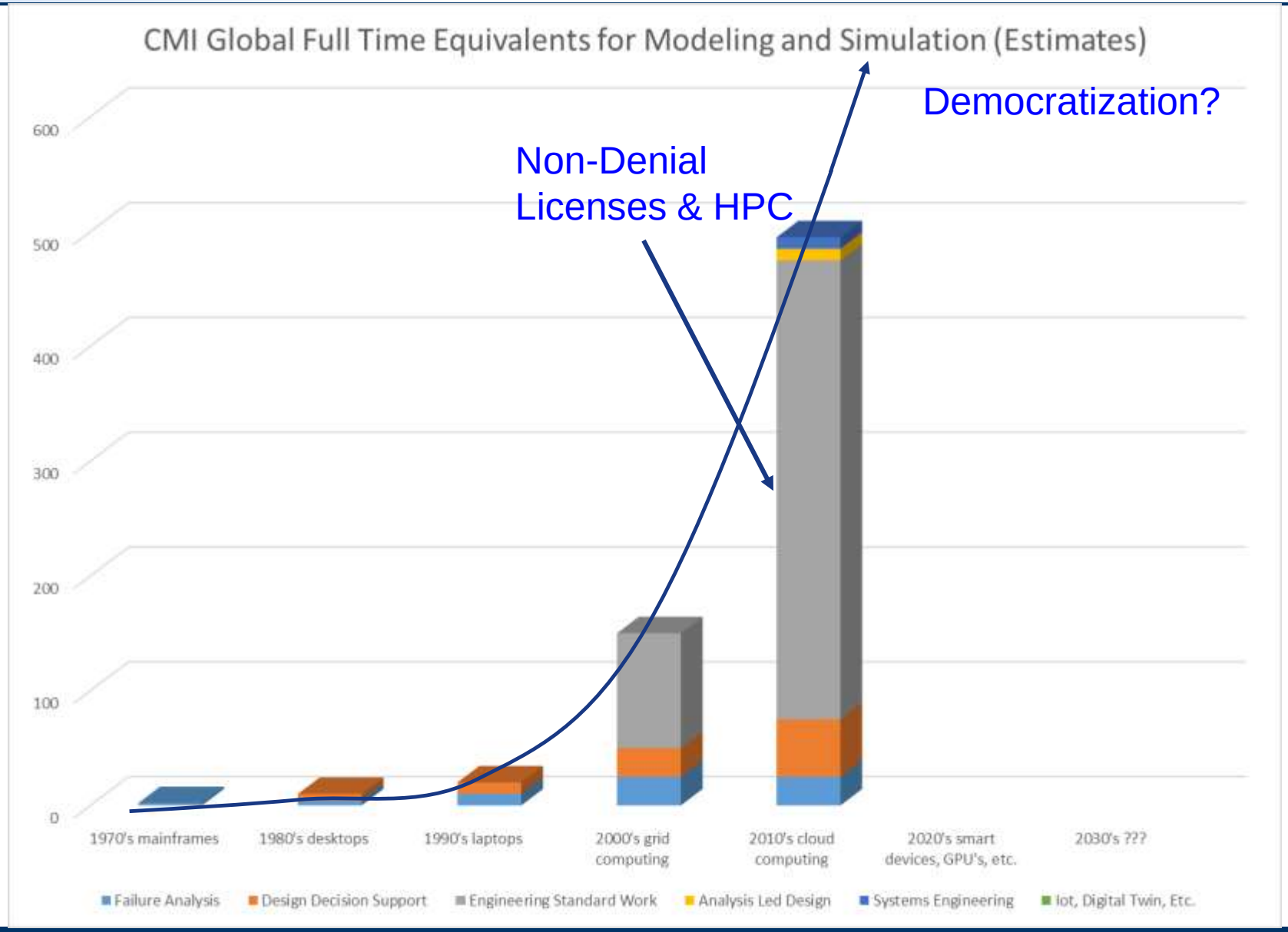
- Through the early 90's analysis was…
  - Component-based
  - Reactive than proactive
- Competing with a successful history of build it – test it
- Top-down ***initiative*** to accelerate the use of analysis arose…
  - Do not run tests unless analysis results are available
  - Reduce/minimize testing based on analysis
  - Achievements in the combustion arena
  - Need for more robust products
  - Best products, delivered on time at lowest cost
  - Etc.
- Excellent proliferation of methods and driven into engineering standard work as critical enabler
- However, dominated by manual iterations and more like "Design-led Analysis Led Design"

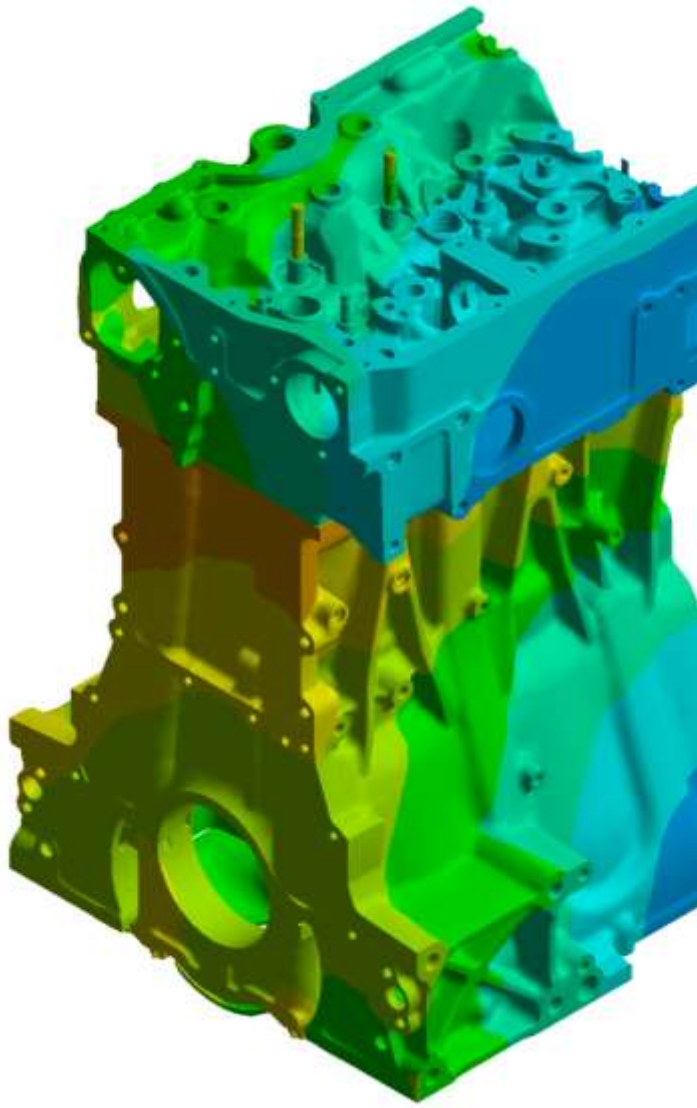


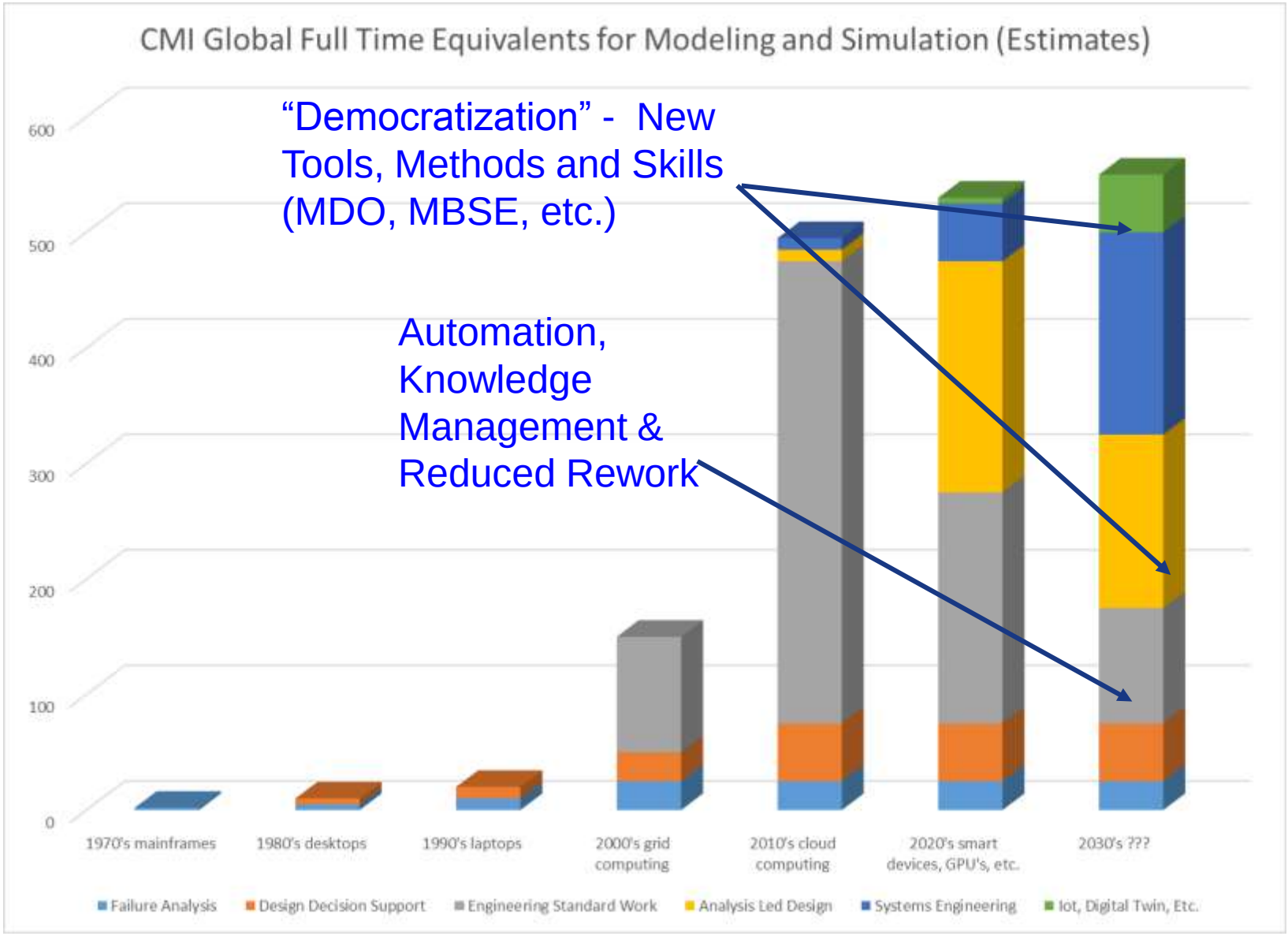
What really is ALD???

- Experts should focus on what they are best at…
  - Generating ideas
  - Defining the right questions/trade-space of interest
  - Interpreting results and making decisions
- ALD augments the decision making of experts, it does not replace them
- It's "quantifying the qualitative" knowledge
- Enabled by…
  - Process Automation
  - Optimization Algorithms
  - Effective data visualization
- **Optimization tools/methods enable *true ALD***




CMI Global Full Time Equivalents for Modeling and Simulation (Estimates)
Democratization?
Non-Denial
Licenses & HPC
600
500
400
300
200
100
0
1970's mainframes
1980's desktops
1990's laptops
2000's grid computing
2010's cloud computing
2020's smart devices, GPU's, etc.
2030's ???
Failure Analysis
Design Decision Support
Engineering Standard Work
Analysis Led Design
Systems Engineering
Iot, Digital Twin, Etc.




CMI Global Full Time Equivalents for Modeling and Simulation (Estimates)
"Democratization" - New Tools, Methods and Skills (MDO, MBSE, etc.)
Automation, Knowledge Management & Reduced Rework
600
500
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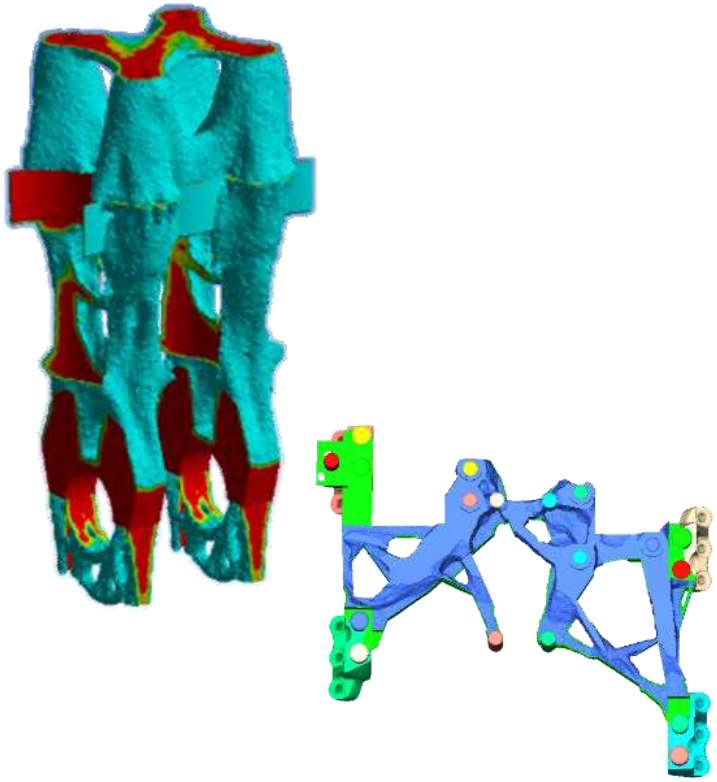
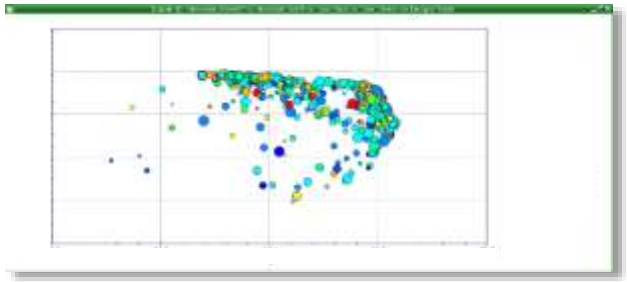
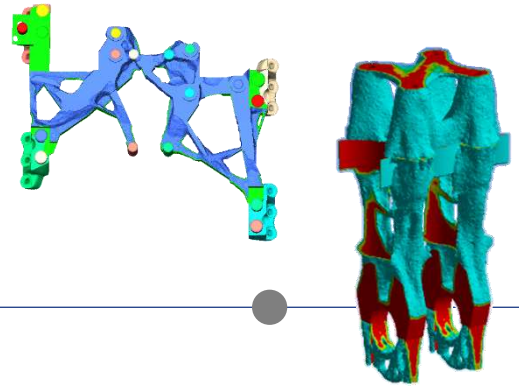




Multidisciplinary Design Optimization Evolution

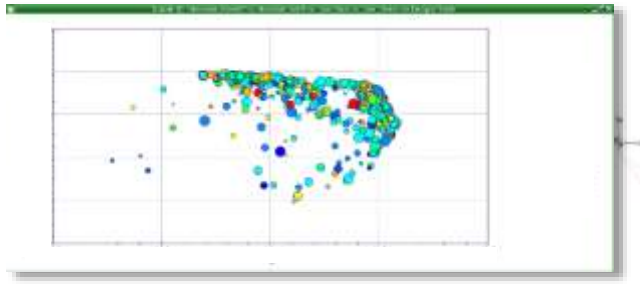


2011

- Topology optimization utilized in few teams globally
- PIDO tools used for automated calibration
- Primarily applied mechanics & PSBU
- **~10 Users**
- **Minimal HPC Usage**

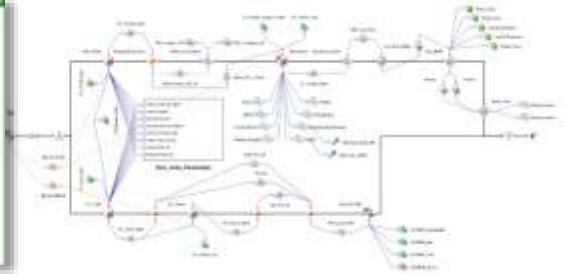
2015

- Single discipline optimization with PIDO tools globally
- Topology optimization utilized in all BUs, globally
- Integrations with ANSYS, GT, Simulink
- Multiple business units
- **~25 Users**
- **Some HPC Usage for long solving physics in loop**



2016

- MDO Proof of concept project completed
- Revealed path for cross discipline optimization
- All business units, globally
- **~50 Users**
- **Heavy HPC Usage for 10s of jobs in parallel – 10000 design points in total**



2017 - 2018

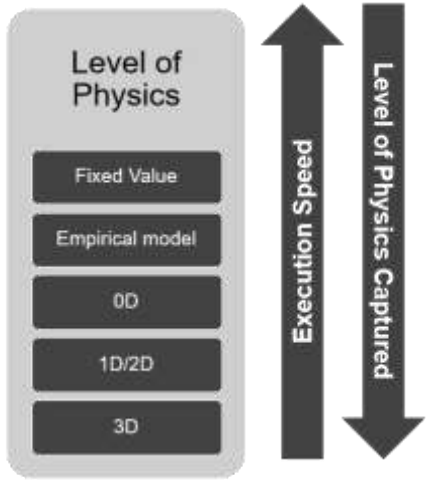
- MDO vision well established and growing in pilot BU
- Designers utilizing topology optimization, globally
- **~100+ users globally**
- **100s of jobs in parallel on HPC – 50000 design points in total**

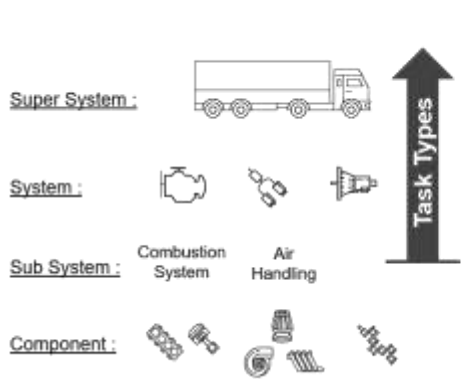
Component-level Optimization

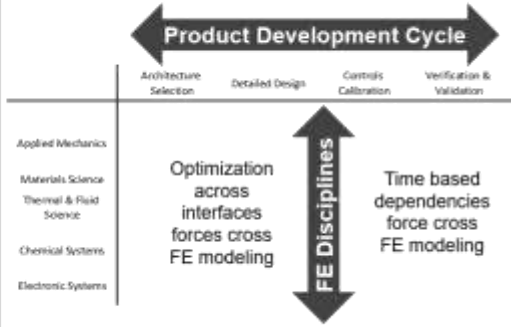
- Primarily structural optimization with some CFD
  - Topology optimization
  - Mesh morphing/parametric shape optimization
- **Impact:**
  - 5 to 10% weight reduction consistently
  - Available to all through integration with democratized toolsets (e.g. GSAM…)
  - Improved performance with less time
  - Enabling sustainability targets for product design
- **Challenges:**
  - Must think optimization first in the design…
  - Interpretation of the optimized result
  - Proliferation of methods/capability globally

People, Tools, Process Developments for MDO

- Automation
- Optimization Strategies/Algorithms
- Multiphysics Analysis
- HPC Usage
- Cross-functional collaboration
- Reduced order models
- Robust design
- Systems Engineering
- Etc.

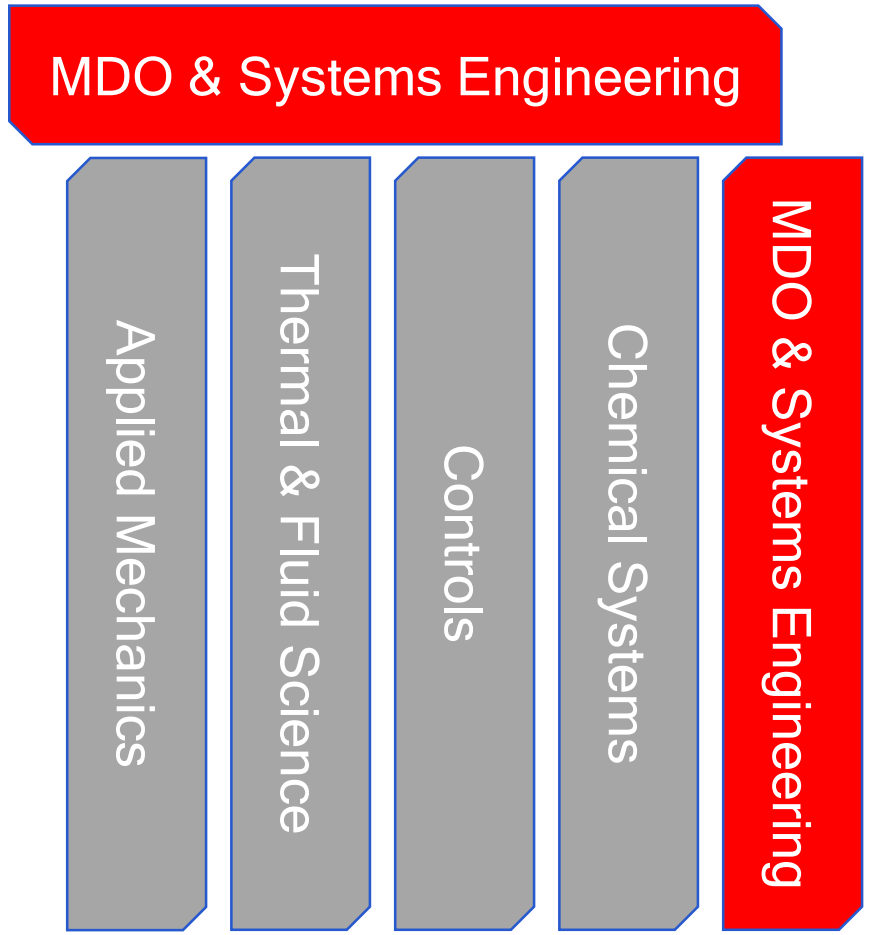






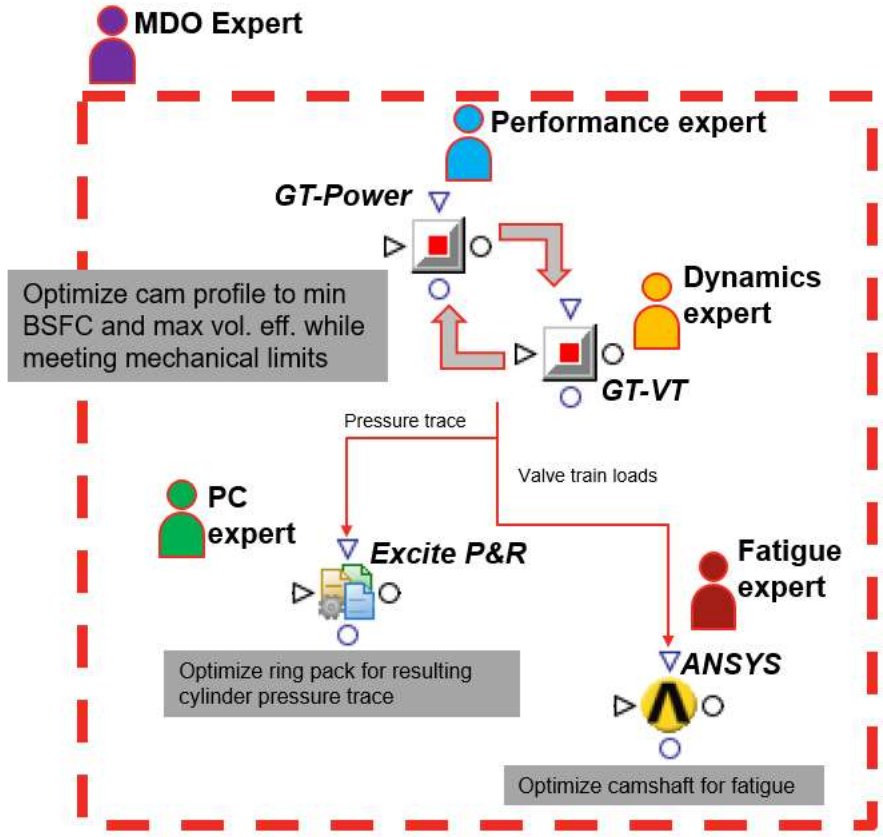
The MDO Culture shift…

- Reducing the “button-clicking” and enabling more decision-making
- Collaboration through our models
- SMEs are critical
  - Quantify their qualitative trade-off knowledge
- Optimization spans across our functional silos
- All of this is just systems engineering!
- **Change is hard…**

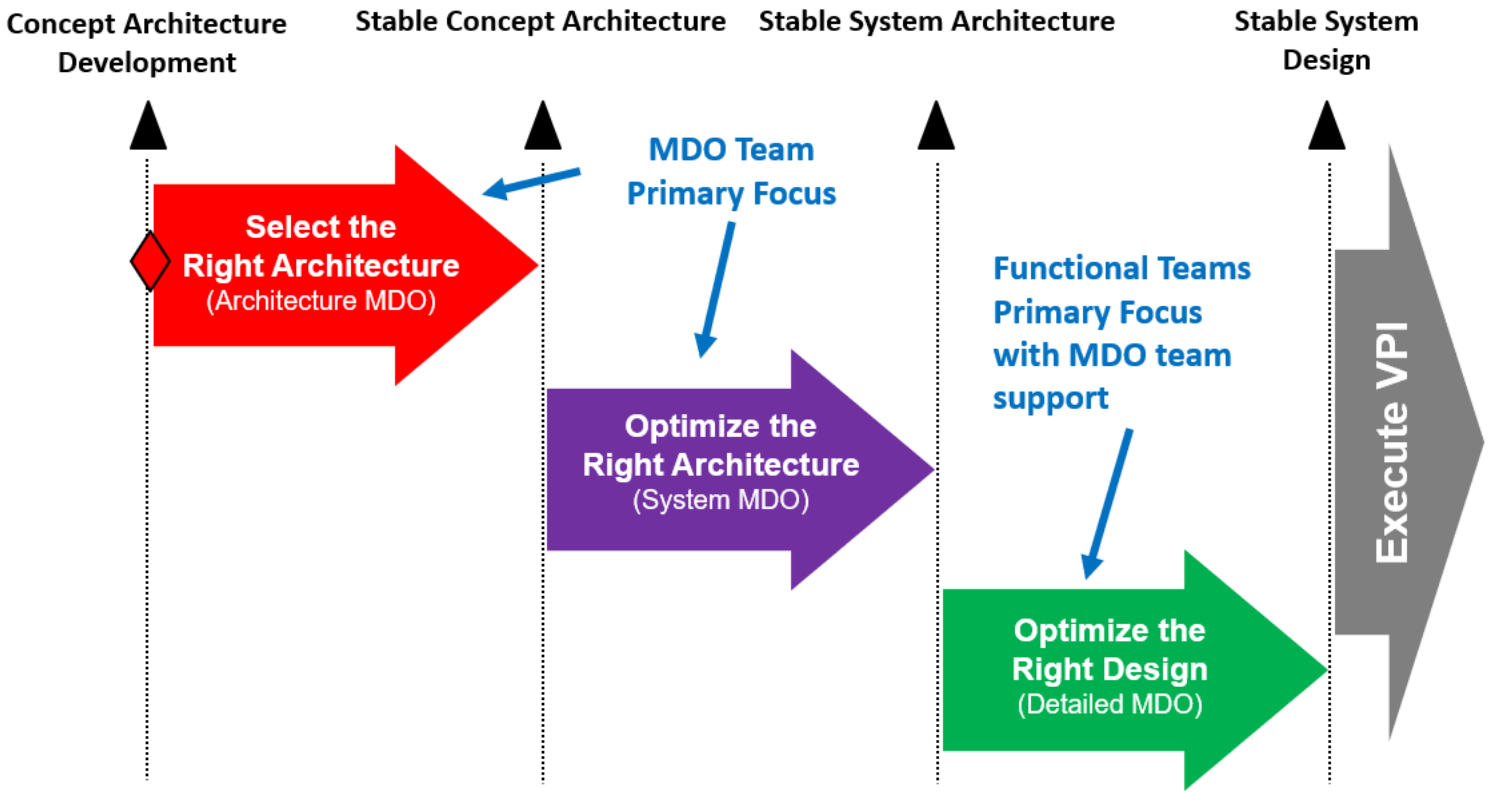


A dedicated team…

- MDO team in PSBU is pilot
  - Composed of members in US, UK & India
- The goal of the team is to be **Complex System Workflow Facilitators**
  - *"Systems Integrators of Models"*
- Expertise in : **Tool integration**, **optimization strategies**, and **data-enabled decision making**
- The MDO team are **NOT** to be experts in all disciplines of modelling. Heavily reliant on FE and technical domain expertise for both model development and review of data (post-processing / decision making)

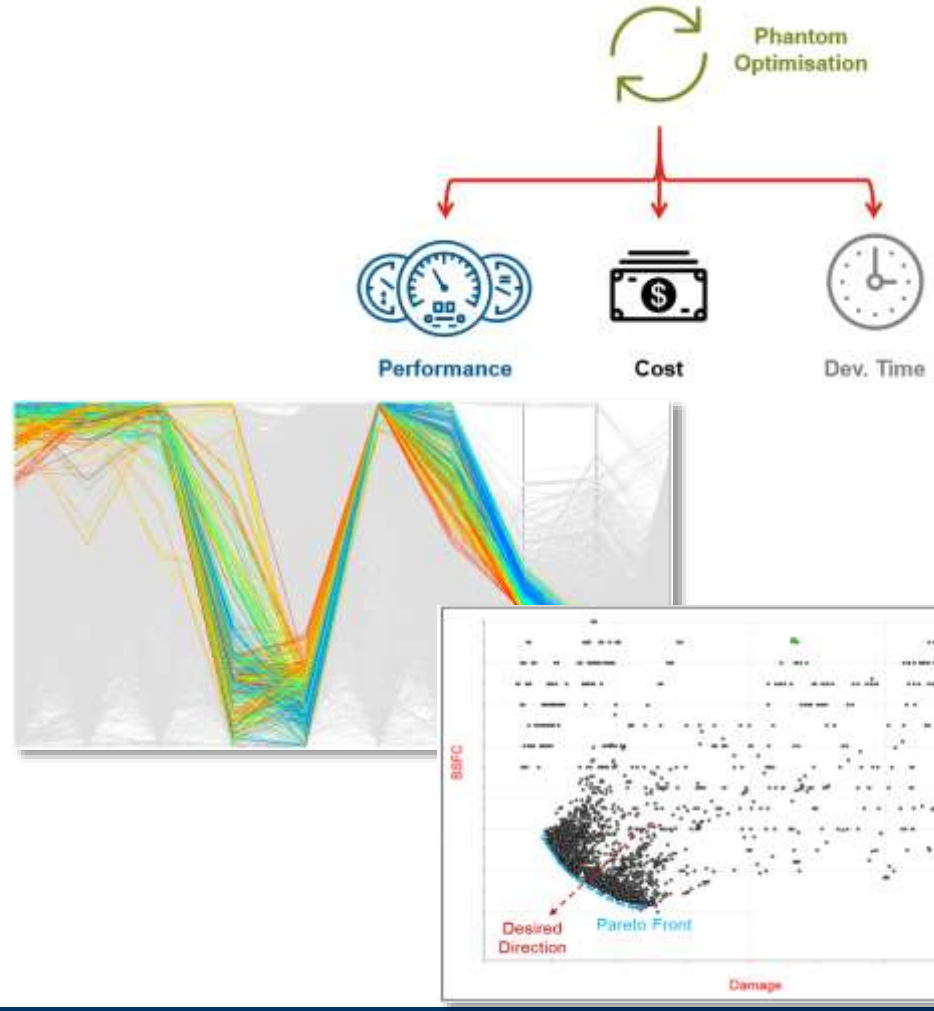


Optimization strategy across product development cycle



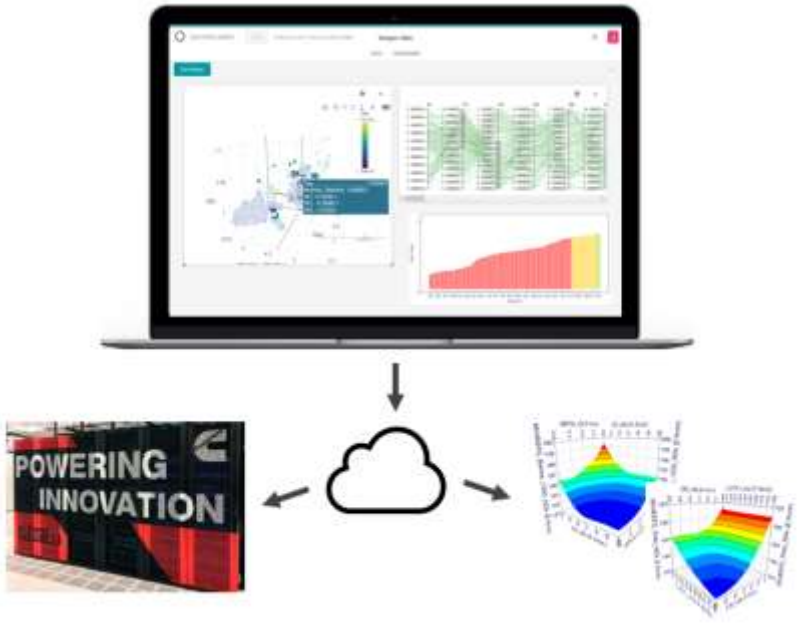
MDO for Architecture

- MDO team bringing ALD methods to the forefront of architecture decisions
- Linking low fidelity models of multiple disciplines
  - Exploring thousands of design options in days
  - Highlighting trade-offs in performance, durability, cost, development time, etc.
- Focusing discussion on pareto designs to help guide decision making upfront…



Opportunities Ahead…

- The roadmap to MDO is becoming more clear…
- To go from good to great…
  - HPC integration/distribution must be streamlined
  - Continued democratization of topology optimization
    - Streamlined interpretation of results
  - Multiphysics/objective approach to structural optimization problems…e.g. TMF
  - Advanced MCDM-like tools to enable decisions
  - “Cloud based” optimization – utilize live data from the field
  - Web platform for MDO to integrate modeling experts and decision makers
  - And more!



Q+A