

From Genesis to High-Performance Computing

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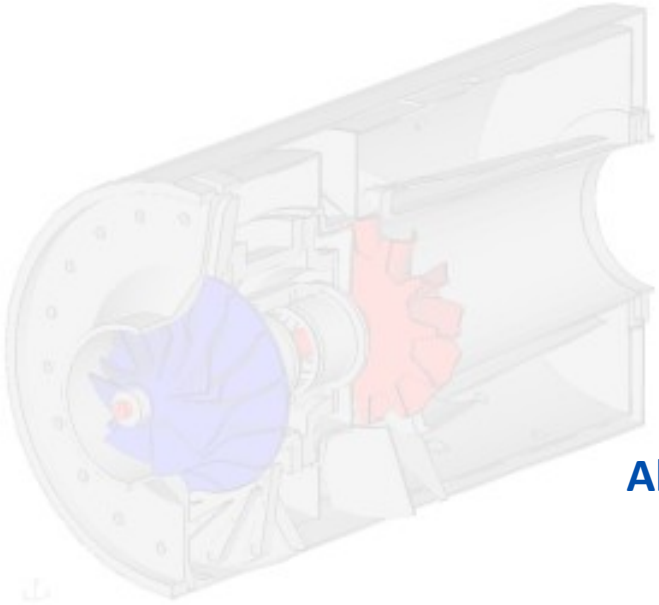
A Power User's 26-Year Journey Through an Open-Source FEM Ecosystem





A Physicist's Perspective on Industrial Simulation

Alessandro Rovera – Physicist & Independent CAE Consultant

CalculiX User Meeting 2026 | 10:40 – 11:00

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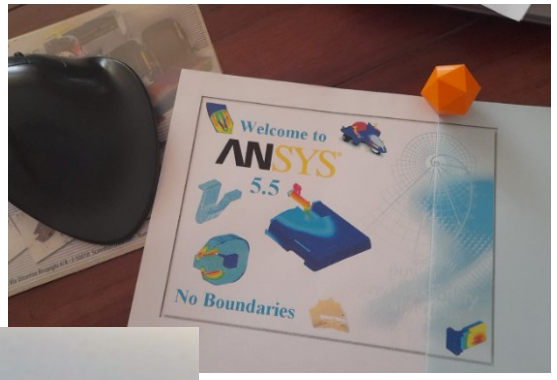
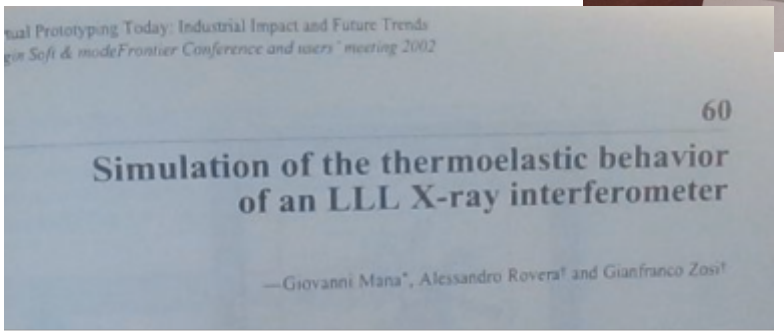
PART 1: The Origin (1994 – 2000)

Academic Roots – A Physicist Meets Galerkin in 1996

- **Academic Background:** Master's Degree in Physics in 2000
- **Mathematical Foundation:** Numerical Methods & the **Galerkin Method** applied to real lab cases.
- **First Solver:** **ANSYS 5.2** (late 1996s)



- **First Publication:**


ual Prototyping Today: Industrial Impact and Future Trends
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Simulation of the thermoelastic behavior of an LLL X-ray interferometer

—Giovanni Mana*, Alessandro Rovera† and Gianfranco Zosi†

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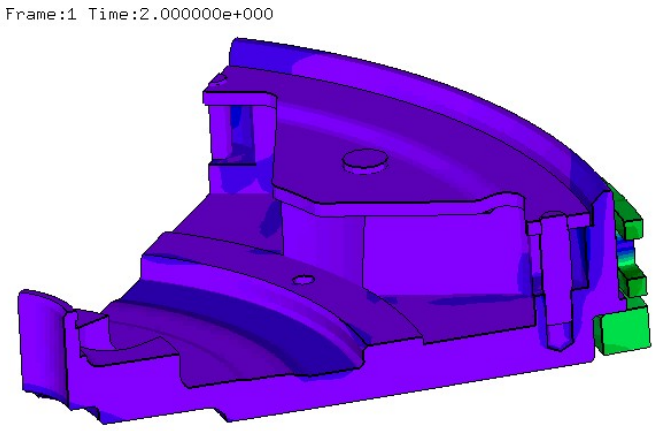
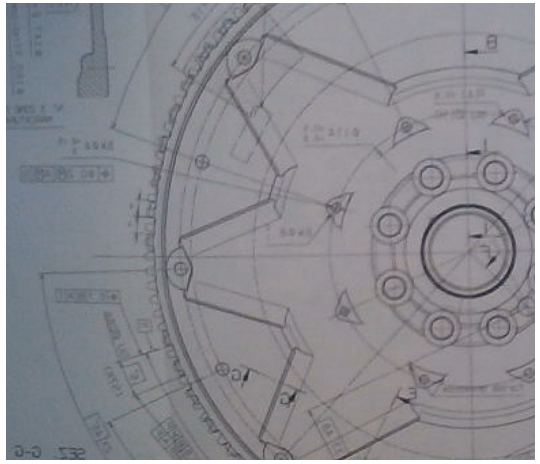
PART 1: The Origin (1994 – 2000)

First Industrial Impact – The Valeo *stage* (Internship)

- **Role:** 6-month post-graduate internship at **Valeo** (Automotive).
- **Key Components:** Radial Dual Mass Flywheels and curved arc springs.
- **Takeaway:** Learned industrial rigor contacts, thermal loads, modal analysis, and mechanical reliability.







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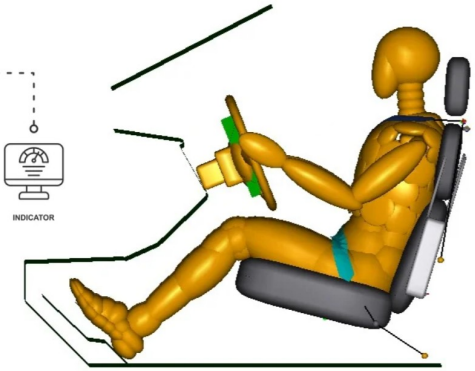
PART 1: The Origin (1994 – 2000)

The Consulting Era – Mastering Commercial Solvers (2000–2008)

- **8 Years in a FEM Consulting Agency:** Solving real industrial cases.
- **Proprietary Toolkit:** **ABAQUS** (non-linear structural), **RADIOSS** (explicit crash/impact), **MADYMO** (multibody & safety), and **Altair HyperMesh**.
- **The Benchmark:** Built deep validation standards to later measure open-source codes against.





Altair Engineering

Altair HyperWorks 8.0

ABAQUS

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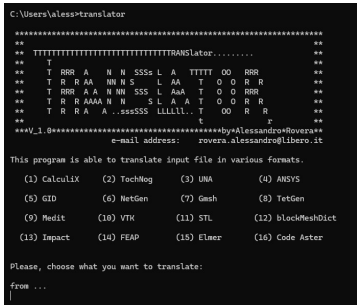
CalculiX – 2026 first user meeting

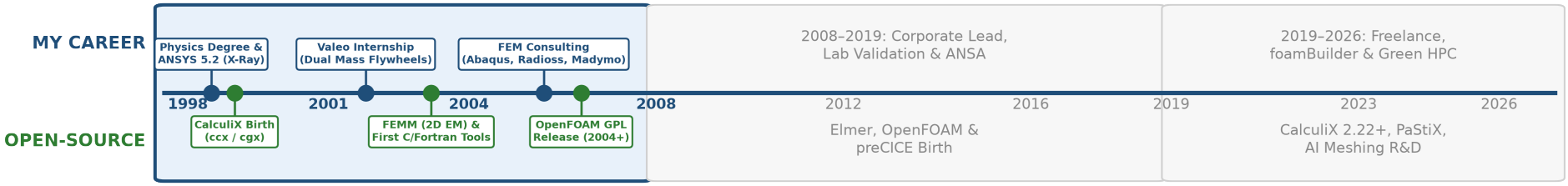
A 26-year journey user experience

PART 1: The Origin (1994 – 2000)



Parallel Tracks – Timeline Part 1 (1998–2008)

- **My Career:** Physics Degree (1998) → Valeo → Commercial FEM Consultant (Abaqus/Radioss/Madymo).
- **Open-Source Genesis:** Birth of **CalculiX** (`ccx/cgx`), **FEMM** (2D Electromagnetics), and **OpenFOAM** GPL release (2004).
- **The Spark:** Noticing CalculiX's Abaqus-like input syntax and coding early custom tools in **ForTran & C**.



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PART 2: The turning point to open-source solutions (2008 – 2019)

Corporate Lead, Open-Source & Lab Validation (2008–2019)

- **Bridging R&D and Testing:** Acted as the technical bridge between the **R&D department** and **two internal testing laboratories (Electrical & Hydraulic)**.
- **Experimental Validation:** Every open-source model—regardless of the physics—was systematically benchmarked and validated against real lab measurements.
- **Zero License fees:** Introduced CalculiX, Elmer, and OpenFOAM into production after proving industrial reliability.

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PART 2: The turning point to open-source solutions (2008 – 2019)

Building the Ecosystem & The Pre-Processing Reality

- **Multi-Physics Solvers & Coupling:** **CalculiX** (Structural/Thermal), **OpenFOAM** (CFD), **FEMM / Elmer** (EM), coupled via **preCICE**.
- **The Pre-Processing Bottleneck:** Open-source pre-processors still lag behind commercial tools for industrial productivity—having used **HyperMesh**, I pushed to purchase **ANSA (BETA CAE)** in-house.

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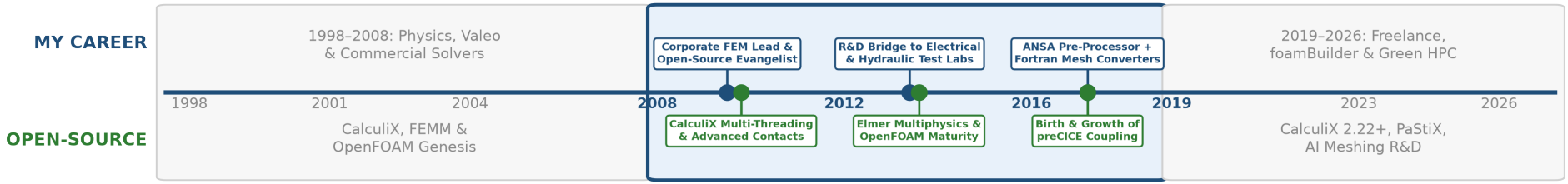
PART 2: The turning point to open-source solutions (2008 – 2019)

Parallel Tracks – Timeline Part 2 (2008–2019)

- **My Career :** R&D & Test Lab Validation ⟶ Hybrid Commercial Pre / Open-Source Solvers ⟶ Custom ForTran/C Tools.
- **Open-Source Ecosystem:** CalculiX multi-threading, OpenFOAM & Elmer maturity, birth of **preCICE**.



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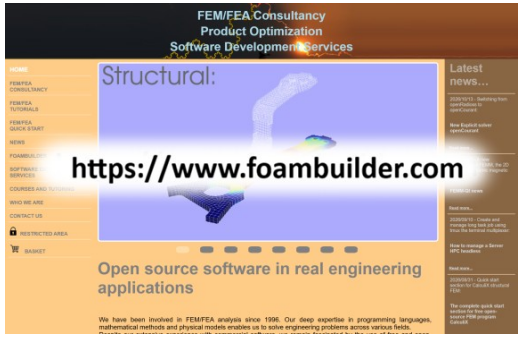
PART 3: The job turning point to freelance (2019 – 2020)

2019 – The Turning Point & `foamBuilder`

- **2019:** Resigned from corporate employment to launch an **independent open-source CAE consultancy**.
- **2020 (Forced lockdown):** Turned lockdown into R&D—developed **`foamBuilder`**, my first GUI-based wizard utility for OpenFOAM.
- **The Digital Shift:** Remote work became feasible; **LinkedIn** unlocked global visibility and led to international clients.



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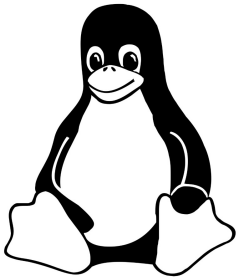
PART 3: The job turning point to freelance (2019 – 2020)

The "Full-Stack" Open-Source CAE Skillset

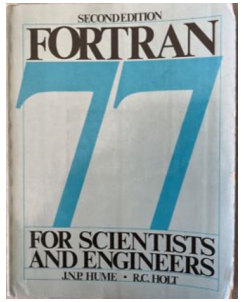
- **Low-Level Programming:** **Bash**, **C**, and **ForTran** for solver customization and workflow automation.
- **Linux & SysAdmin Mastery:** Living in the Linux shell, managing dependencies, and configuring multi-core servers.
- **Compiling from Source:** Building CalculiX, OpenFOAM, and Elmer with custom math libraries (Pardiso, PaStiX, MPI) and patching source code when required.

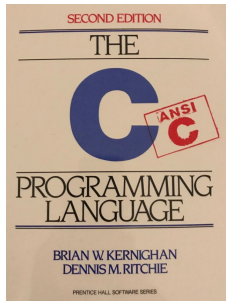












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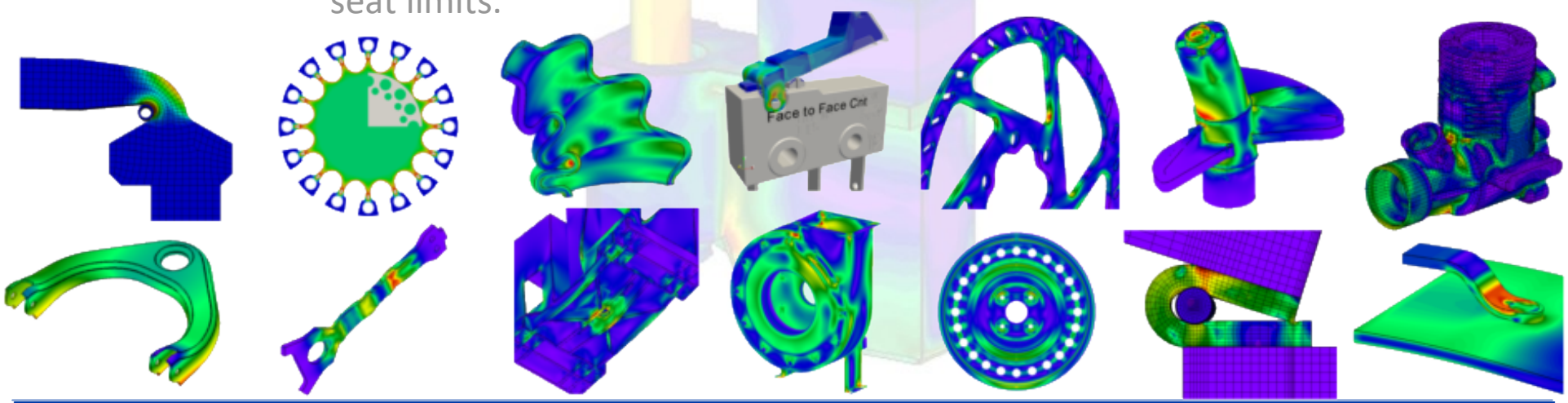
PART 4: Case Studies & Software Development (2019 – 2026)

Case Study 1 – Non-Linear & Thermo-Mechanical Analysis (CalculiX)

- **Solver:** CalculiX (ccx).
- **Physics:** Large deformations, plasticity, complex surface-to-surface contacts, and transient thermal-stress coupling.
- **Highlight:** High-accuracy stress prediction on industrial assemblies without commercial seat limits.



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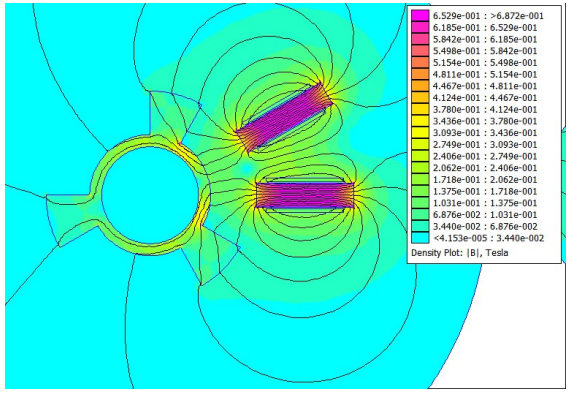
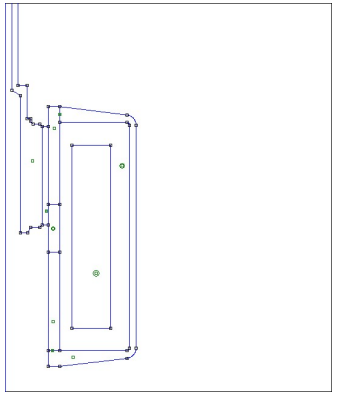
PART 4: Case Studies & Software Development (2019 – 2026)

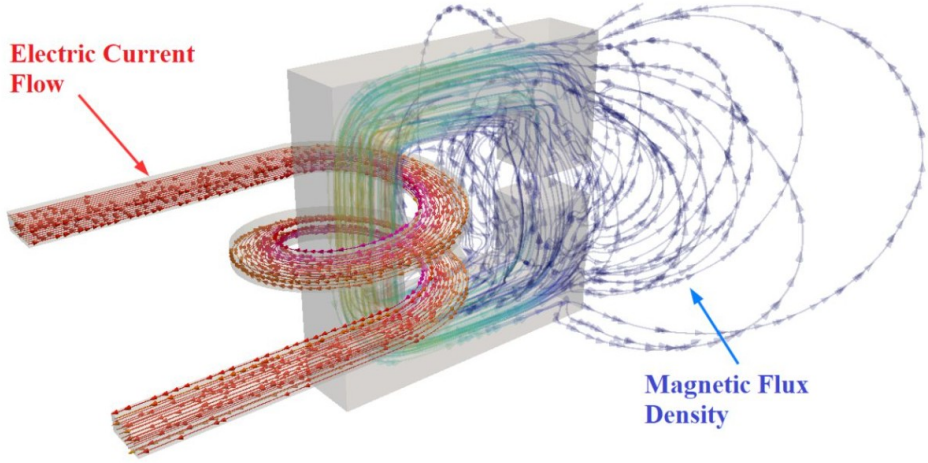
Case Study 2 – Dynamic Electromagnetics via FEMM + Lua & Elmer

- **FEMM + Lua Scripting:** Coupling magnetostatics with **Lua scripts** to integrate equations of motion—turning static runs into **dynamic electromagnetic simulations** including **eddy current losses** (rooted in Physics II fundamentals).

- **Elmer Multiphysics:** Full 3D electromagnetic, induction heating, and coupled field problems.







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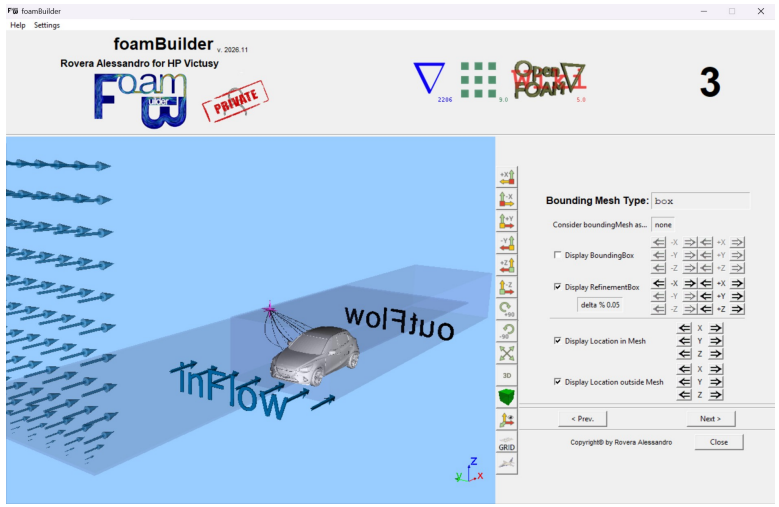
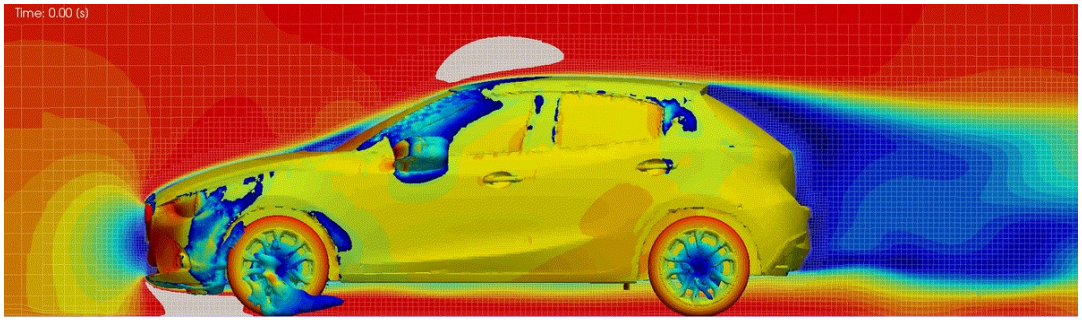
PART 4: Case Studies & Software Development (2019 – 2026)

Case Study 3 – Industrial CFD & foamBuilder Workflows (OpenFOAM)

- **Solver:** OpenFOAM accelerated by `foamBuilder`.
- **Physics:** Internal/external aerodynamics, pressure drop optimization, and Conjugate Heat Transfer (CHT).
- **Highlight:** Automated meshing and case setup via custom GUI and Bash pipelines.





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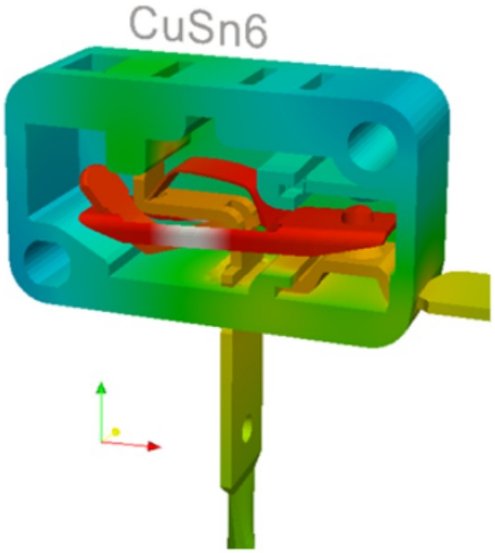
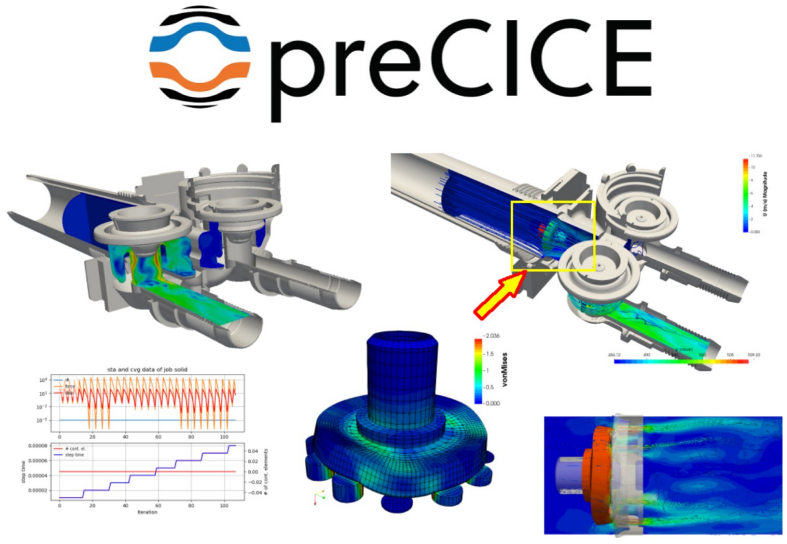
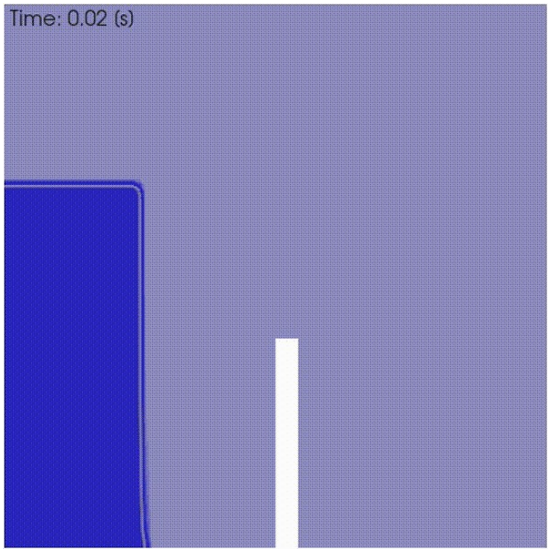
PART 4: Case Studies & Software Development (2019 – 2026)

Case Study 4 – True Multi-Physics Coupling (preCICE)

- **Coupling:** **preCICE** for partitioned multi-physics (FSI / CHT) + custom high-speed data mappers.
- **Physics:** Seamless transfer of fluid pressures, thermal loads, and EM losses onto structural domains.







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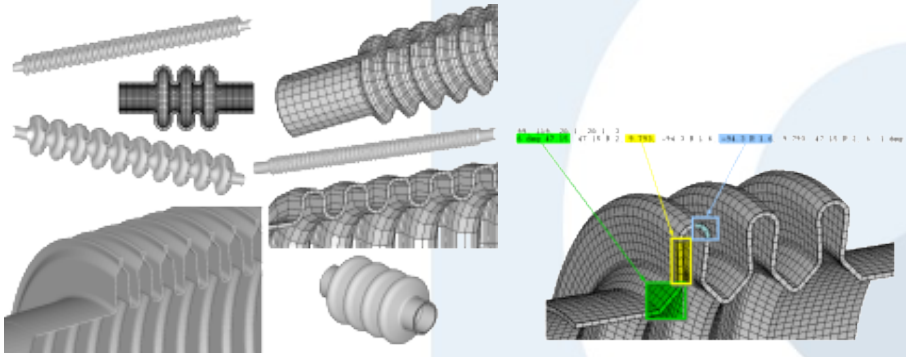
PART 4: Case Studies & Software Development (2019 – 2026)

Under the Hood – Custom C Applications & cgx Automation

- **CalculiX cgx & Parametric Automation:**

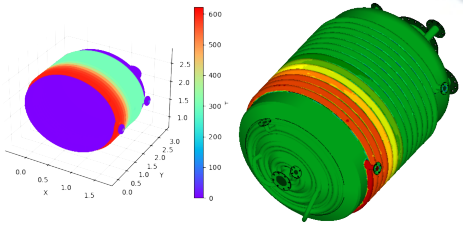


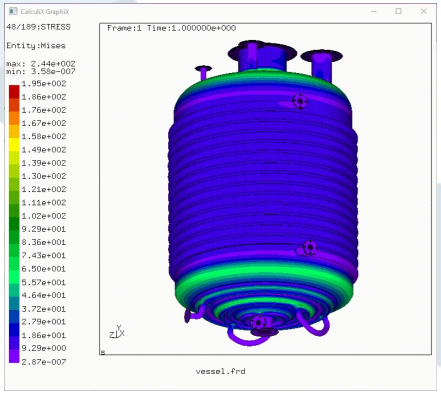
Built a custom **C application** for **Union C. LTD (South Korea)** to fully automate the FEM model generation of industrial expansion bellows.

UNION
https://www.unions.co.kr/

- **High-Speed Non-Conformal Mapping:**

M-Star Calculix





Developed a memory-efficient **C mapper** for a **US client** to transfer **M-Star CFD** results (millions of cells/nodes) onto non-conformal **CalculiX** structural meshes.

LATTICEPT
https://latticept.com/

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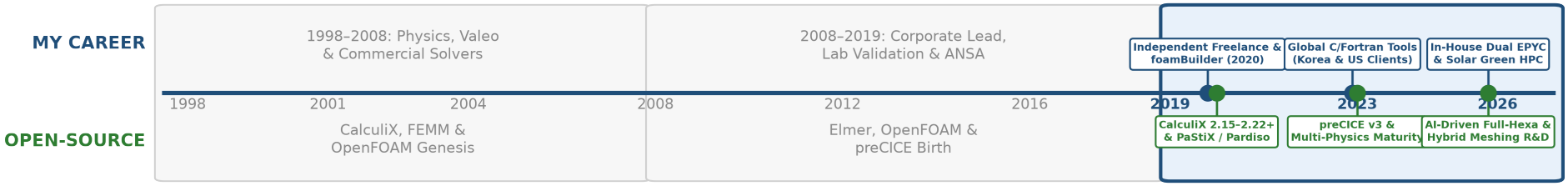
PART 4: Case Studies & Software Development (2019 – 2026)

Parallel Tracks – Timeline Part 3 (2019–2026)

- **My Career:** Freelance → `foamBuilder` → Global C/ForTran Engineering Tools → In-House Green HPC.
- **Open-Source Ecosystem:** CalculiX 2.15–2.22+, PaStiX/Pardiso, preCICE v3.
- **Convergence:** Individual expertise meets massive open-source computing power.



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PART 5: HPC, Green Energy & new R&D Frontier (2024 – 2026)

Bringing HPC In-House – AMD Dual EPYC 7b13 Architecture

- **The Hardware Leap (Last 2 Years):** Dedicated **AMD Dual EPYC 7b13 Series** server for large-scale multi-physics runs.
- **Architecture-Aware Compilation:** Building solvers from source with CPU-specific flags (`-march=znver3`, OpenMP, MPI, Pardiso/PaStiX) tuned for NUMA topology.
- **Headless Remote Workflow:** Managing FEM-FEA jobs via **SSH**, persistent **tmux** sessions, and automated Bash pipelines.





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PART 5: HPC, Green Energy & new R&D Frontier (2024 – 2026)

Green HPC – Powering Simulations with Solar Energy

- **The Hidden Cost of In-House HPC:** Running a Dual EPYC node under full load 24/7 makes electricity the new "license fee."
- **The Sustainable Solution:** Installed a dedicated **Photovoltaic (PV) system with battery storage** engineered to sustain the HPC load.
- **Near-Zero OPEX & Carbon-Neutral:** Scheduling heavy solving during peak solar hours and relying on batteries overnight—achieving **green, self-sustained engineering**.

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PART 5: HPC, Green Energy & new R&D Frontier (2024 – 2026)

What's Next – Current R&D & AI-Driven Meshing

- **Hybrid Boundary-Layer Meshing (OpenFOAM):** Custom pipeline combining `snappyHexMesh` with **tetrahedral/pyramid transitions** to guarantee **true 100% full boundary layer coverage** on complex geometries.
- **AI Agent for Full-Hexa Structural Meshing:** Developing an intelligent agent that analyzes geometry, executes strategic cuts, and drives primitive algorithms (**sweep, extrude, spin**) to automate **full-hexahedral meshes** for CalculiX.
- **26-Year Takeaway:** Physics + Low-Level Code + AI Automation = Complete Engineering Freedom

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Thank You for Your Attention!

A Physicist's Perspective on Industrial Simulation

Alessandro Rovera – Physicist & Independent CAE Consultant

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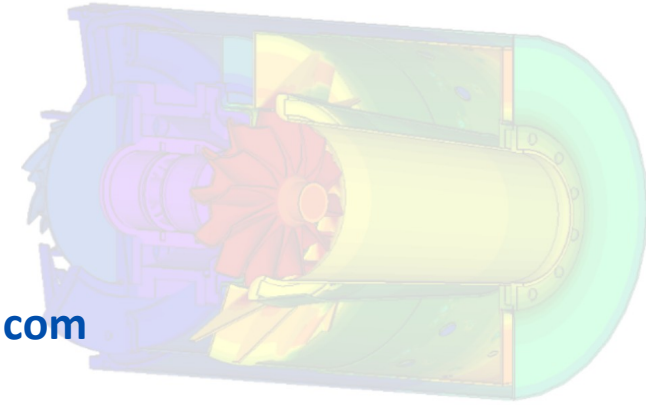

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