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Simple, Quick, and Reliable Simulation Process Automation

Low-Code Tools for Systematic Democratization

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Finding a Path to Simulation Democratization

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The Path to Simulation

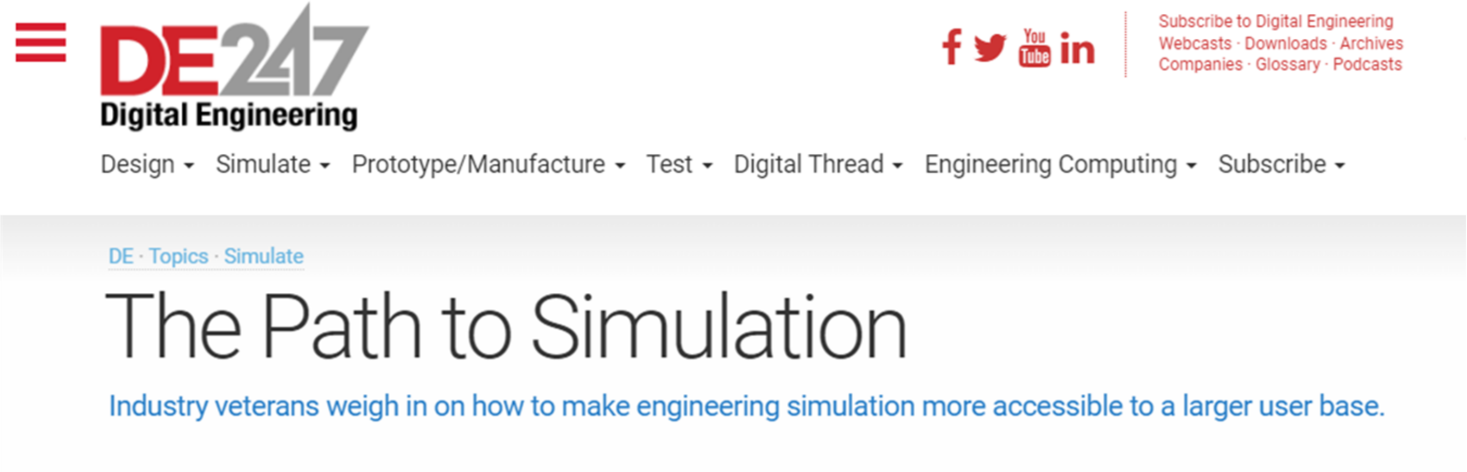
Industry veterans weigh in on how to make engineering simulation more accessible to a larger user base.

By Brian Albright
September 1, 2019

Boosted by new, easier to use tools and more readily available compute resources, simulation technology is increasingly used more frequently and earlier in the design process, and by a wider array of professionals.

However, the path to truly democratized simulation requires both technological and cultural changes. *Digital Engineering* spoke with some leading industry organizations about progress toward this democratization, and some of the remaining challenges and opportunities.

Finding a Path to Simulation Democratization



- **The path to truly democratized simulation requires both technological and cultural changes.**
- **Expert knowledge capture and reuse are critical.**
- **You must automate your simulations. That's the only way this can be done.**
- **We're at the point now that automation is essential for all sorts of reasons, not just democratization.**
- **You also need a path where these tools are packaged in a form that others, who don't need to be experts, are exposed to their power.**

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A Difficult Path for Broader Access to Simulation

In today's environment, **even those tools that allow you to create such automation require a lot of programming and scripting. That increases the cost of implementing democratization and makes it challenging to maintain.**

Up-front effort too often too high for broad use of automated simulation processes.

RevSim Webinar

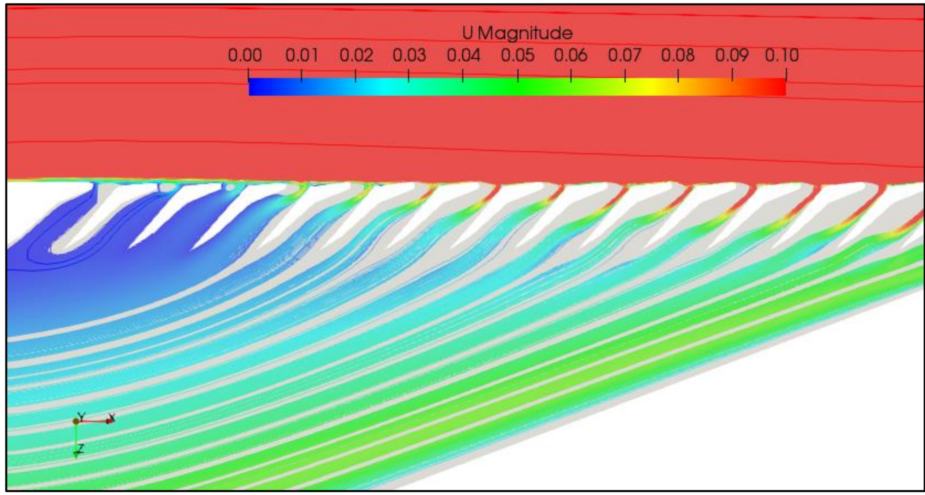
Fast and Easy Simulation Automation Accelerates Innovation at PAX Scientific for US Navy +

All CFD simulations needed for our projects are executed **through automated processes**

– PAX has used Fluent, CCM+ and AcuSolve in past projects and is now using OpenFoam

Project Examples

– Low temperature vacuum distillation
  - Applications for the US Navy and Oil & Gas industry include generation of hydrogen and potable water from seawater by combining an electrolyzer and PAX multiple-effect distillation
– Fans: industrial, automotive, consumer
– Hydro and wind turbines
– Heat exchanger fins and turbulators



PAX - Company Background

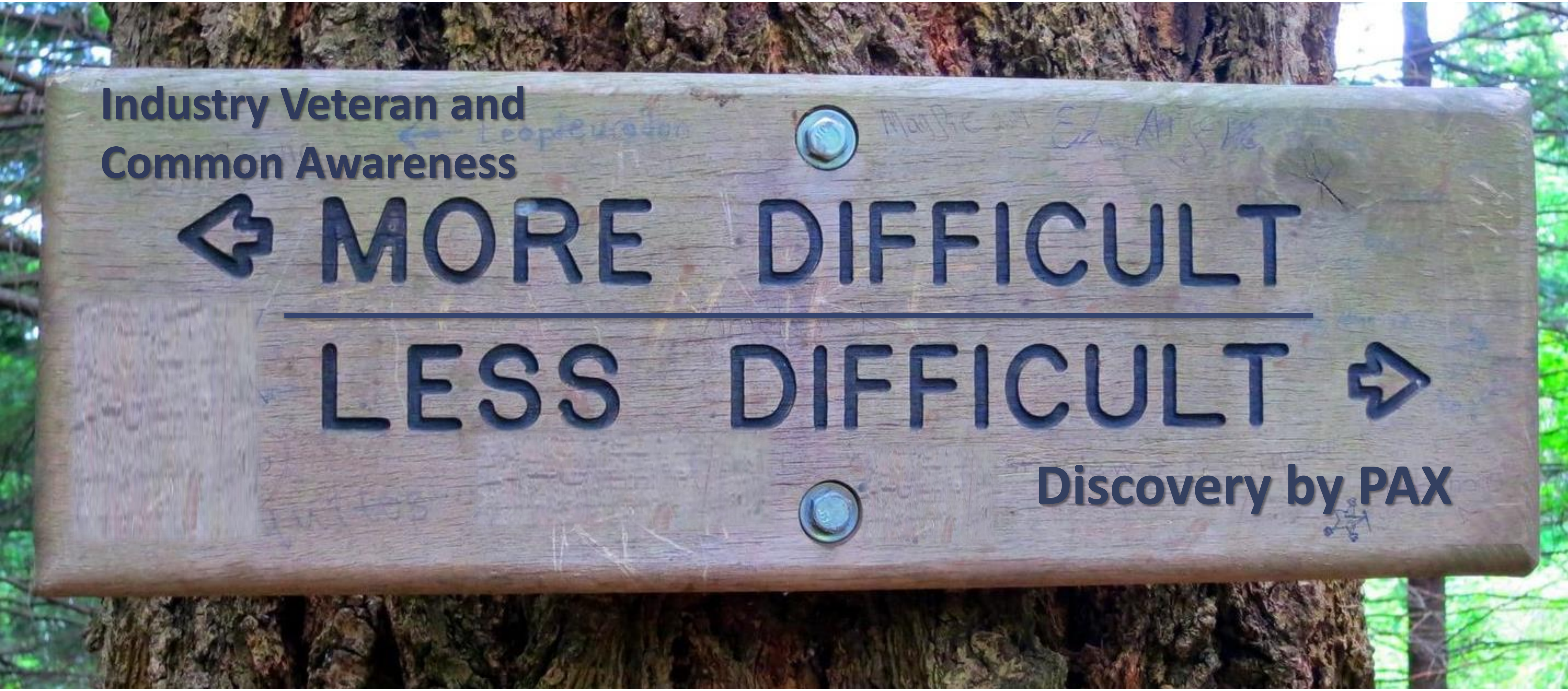
- Nature-inspired research and development fluids engineering firm
- PAX applies vortex flow geometries (biomimicry) to dramatically improve performance of air and fluid-handling components and systems
- PAX conducts internal and client-contracted R&D and licenses to manufacturers or launches new entities to commercialize products
- **One CFD analyst and one CAD specialist**







Finding a Path to Simulation Democratization

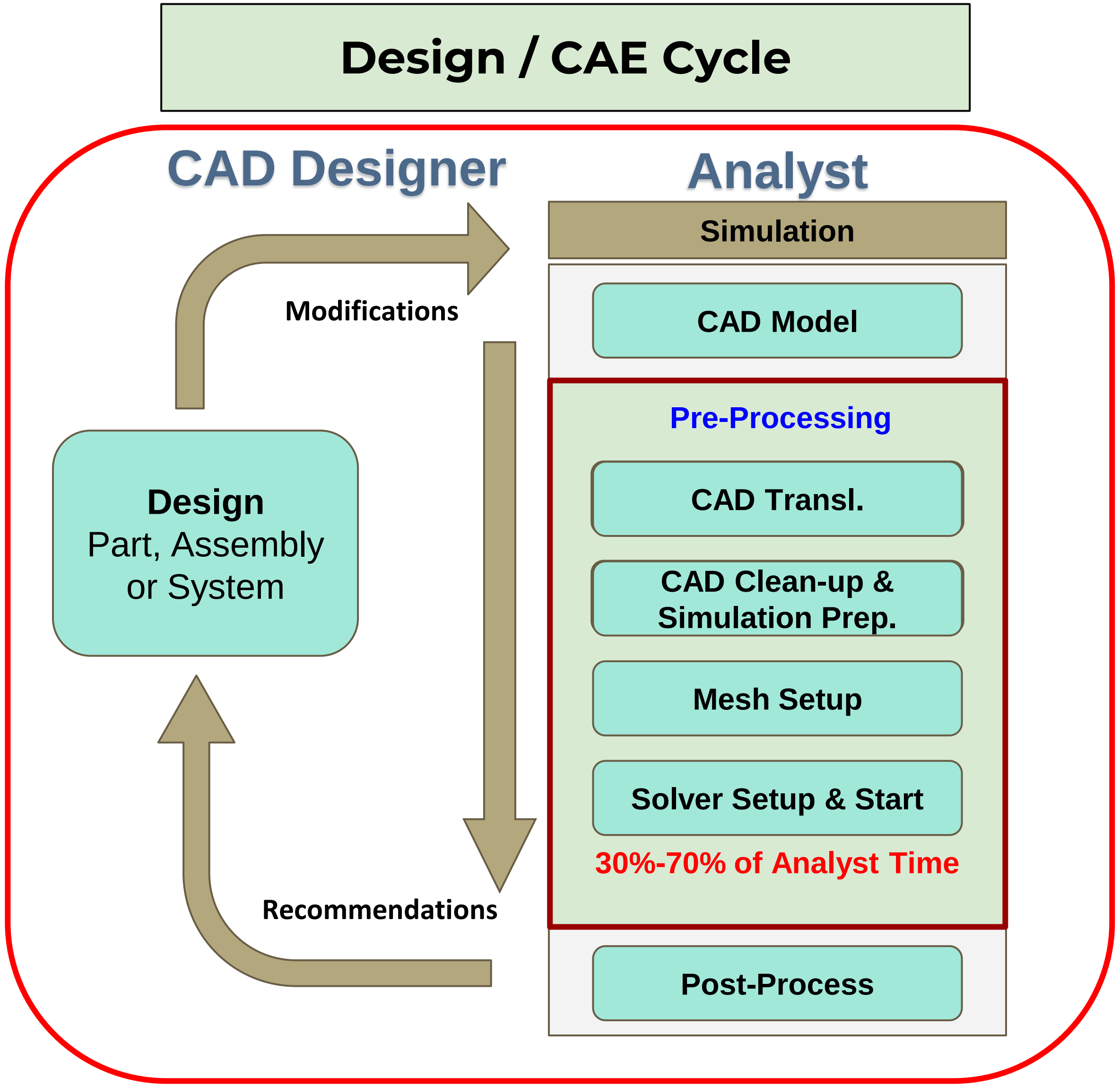


THE WELL TRAVELED PATH DILEMMA

"If I would have asked people what they wanted, they would have said faster horses."

- Henry Ford

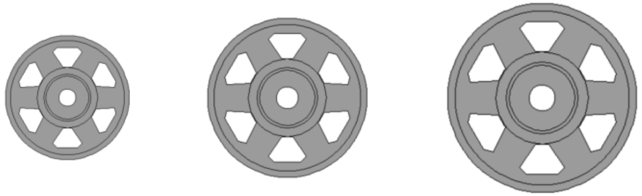
Traditional CAD to CAE Process



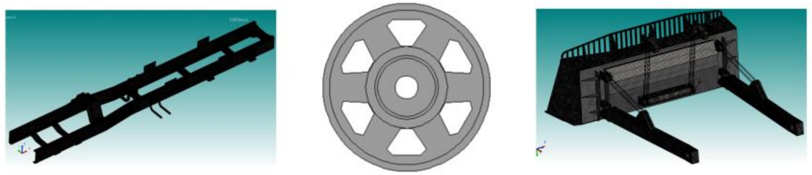
Automation in Traditional CAE Processes

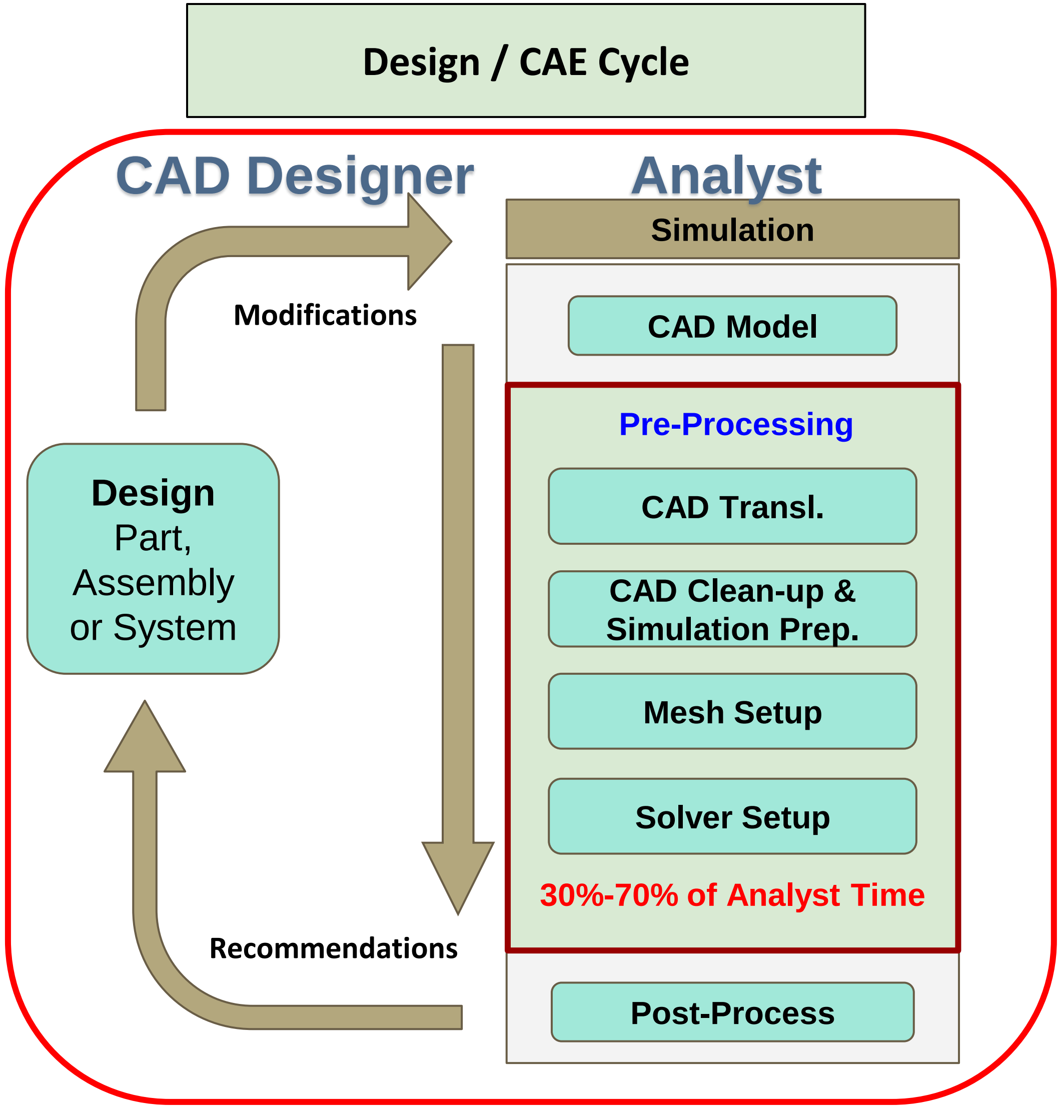
Automation possible but **requires a lot of programming and scripting, especially with regards to geometry changes.**

- Works OK for predictable geometry



- But extremely difficult for greatly varying geometry





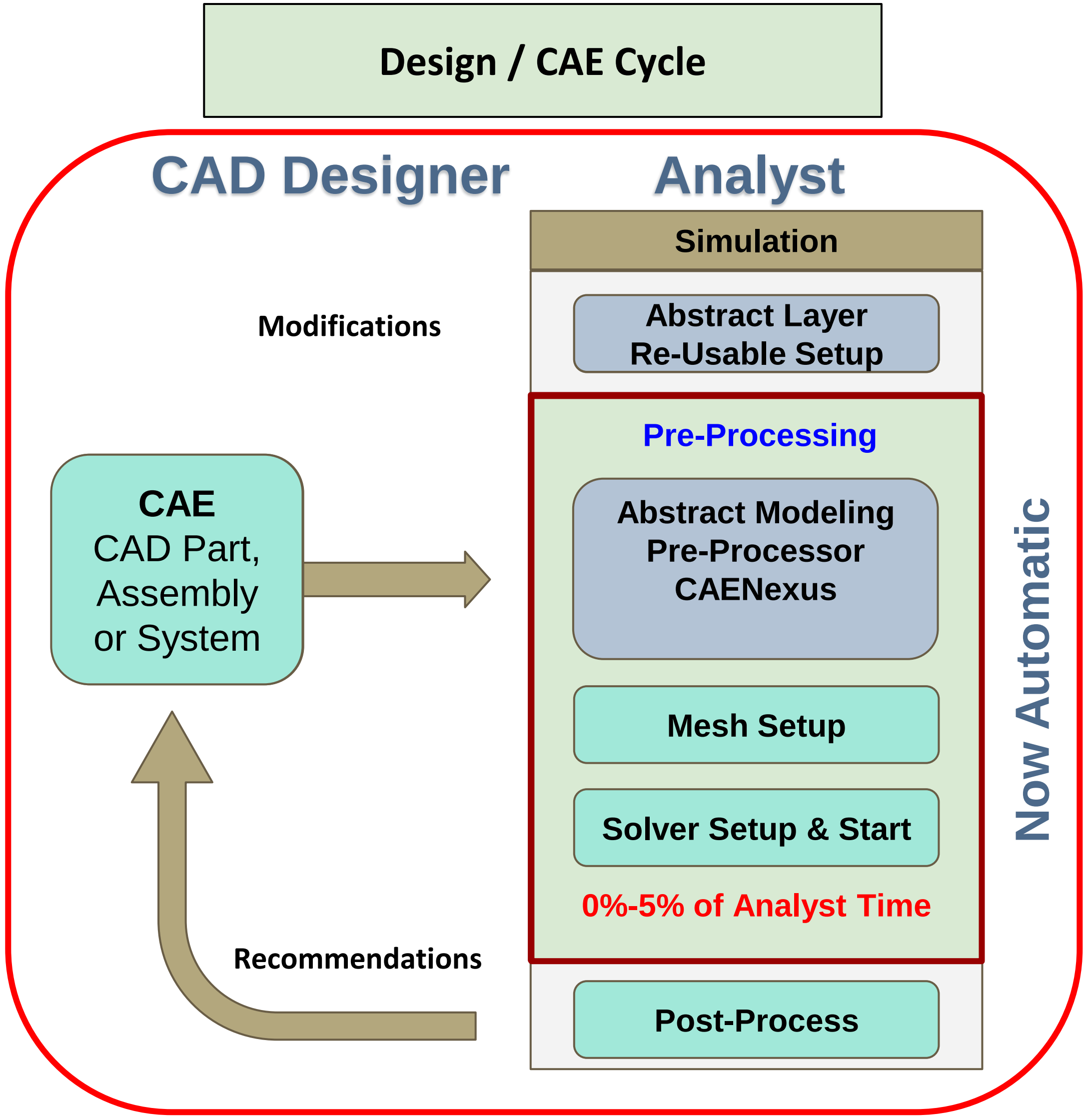
Overcoming the Well Traveled Path Dilemma

Making the switch from

"Geometry Dependency" to

"**Geometry Independency**"

- Reusable, geometry independent simulation templates, or "Abstract Models"
- Automation by abstract model configuration



Special Low-Code solution for CAD-to-Solver process and Report Generation

Low-Code: Configuring instead of programming/scripting

1. Configure geometry independent, re-usable simulation template (AM)
   - ✓ Mesh parameters, solver settings, report content
2. Create CAE ready CAD models
   - ✓ Text attributes
   - ✓ Simulation “view” (e.g., fluid space instead of manufacturing CAD)
3. Submit to CAENexus (via batch command or Universal Low-Code tool)
   - ✓ Automatic mesh creation
   - ✓ Automatic solver input files creation
   - ✓ Automatic report generation (new feature – pre-release)

THE NEW PATH POSSIBILITIES

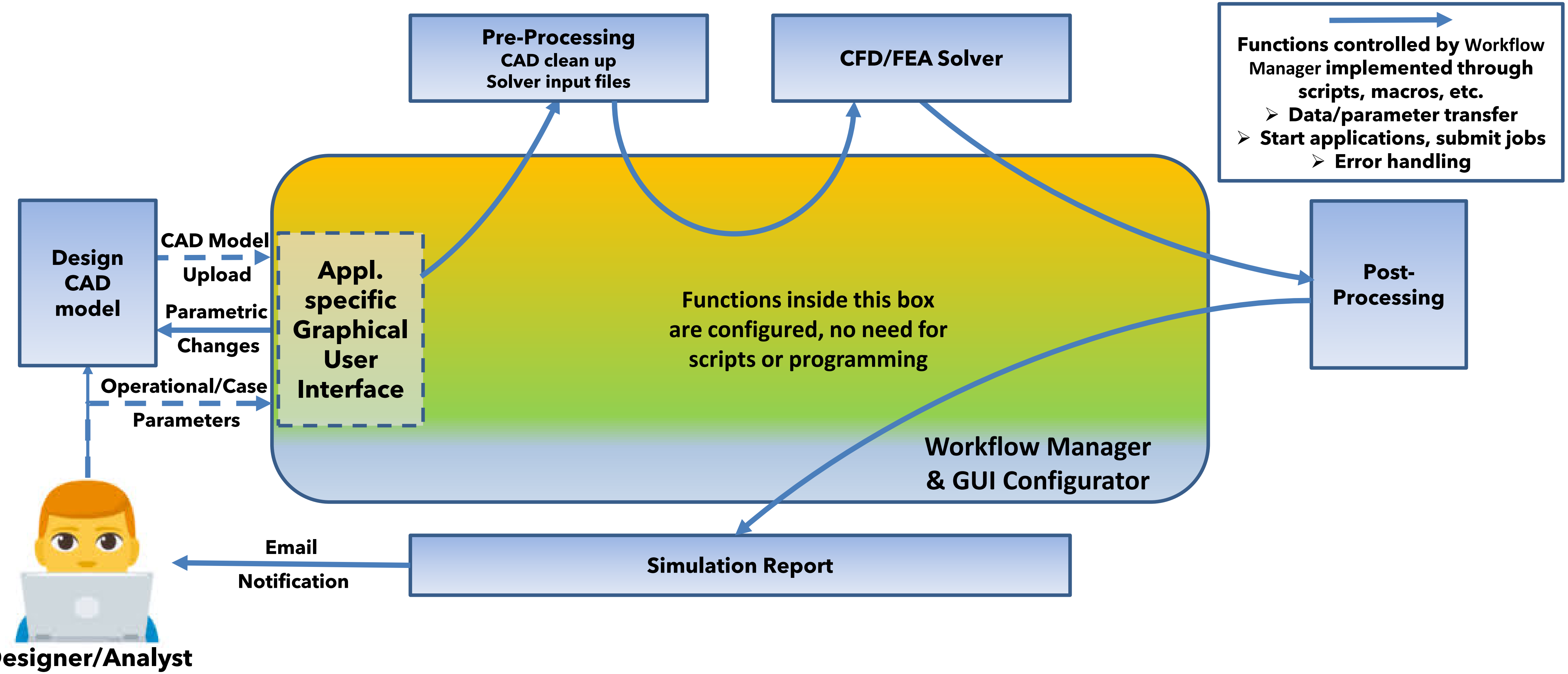
Low-Code Tools: A More Efficient Way to Simulation Democratization

Easier Automation with Low-Code Tools

- Multiple types of Low-Code Tools available
  - Universal (general-purpose)
  - Simulation-specific
- Strength:
  - Workflow management
  - Custom GUI builder
  - CAD to Solver, including report generation, “black box” automated

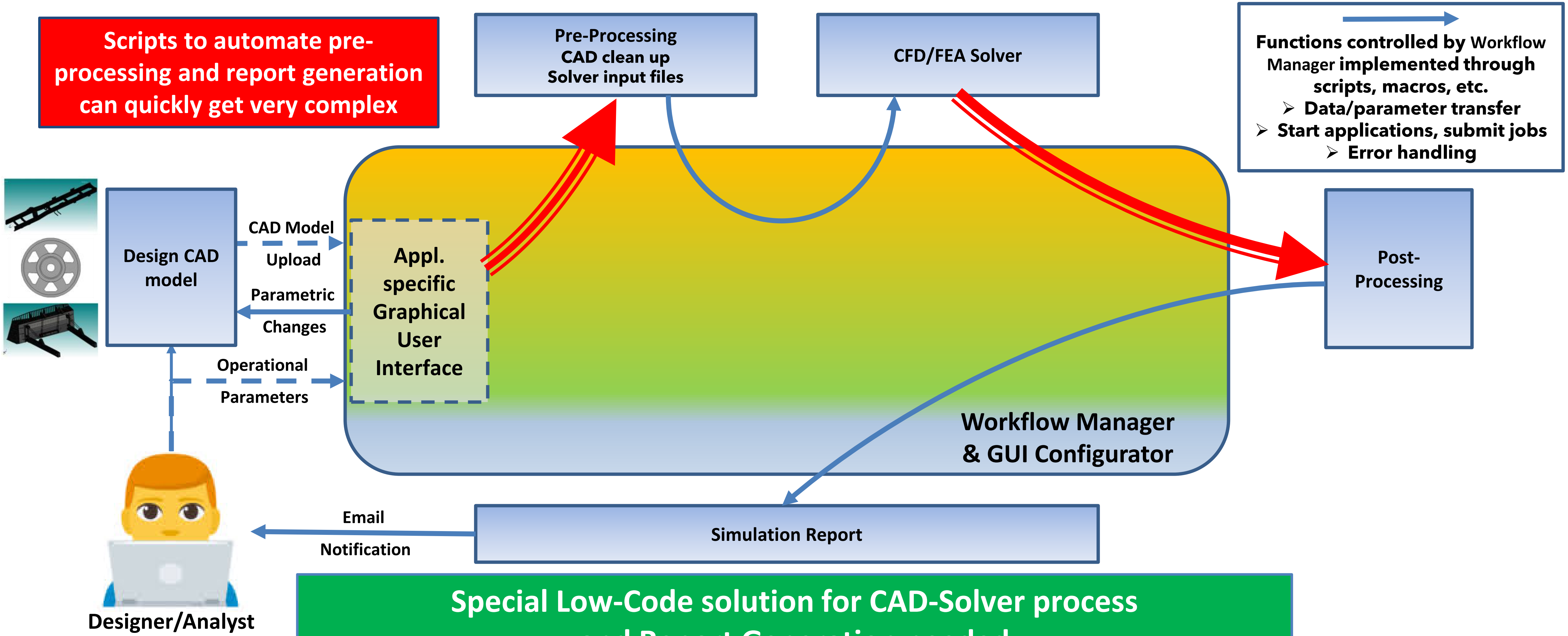
Automated Simulation Process

Universal Low-Code Tool Only



Automated Simulation Process

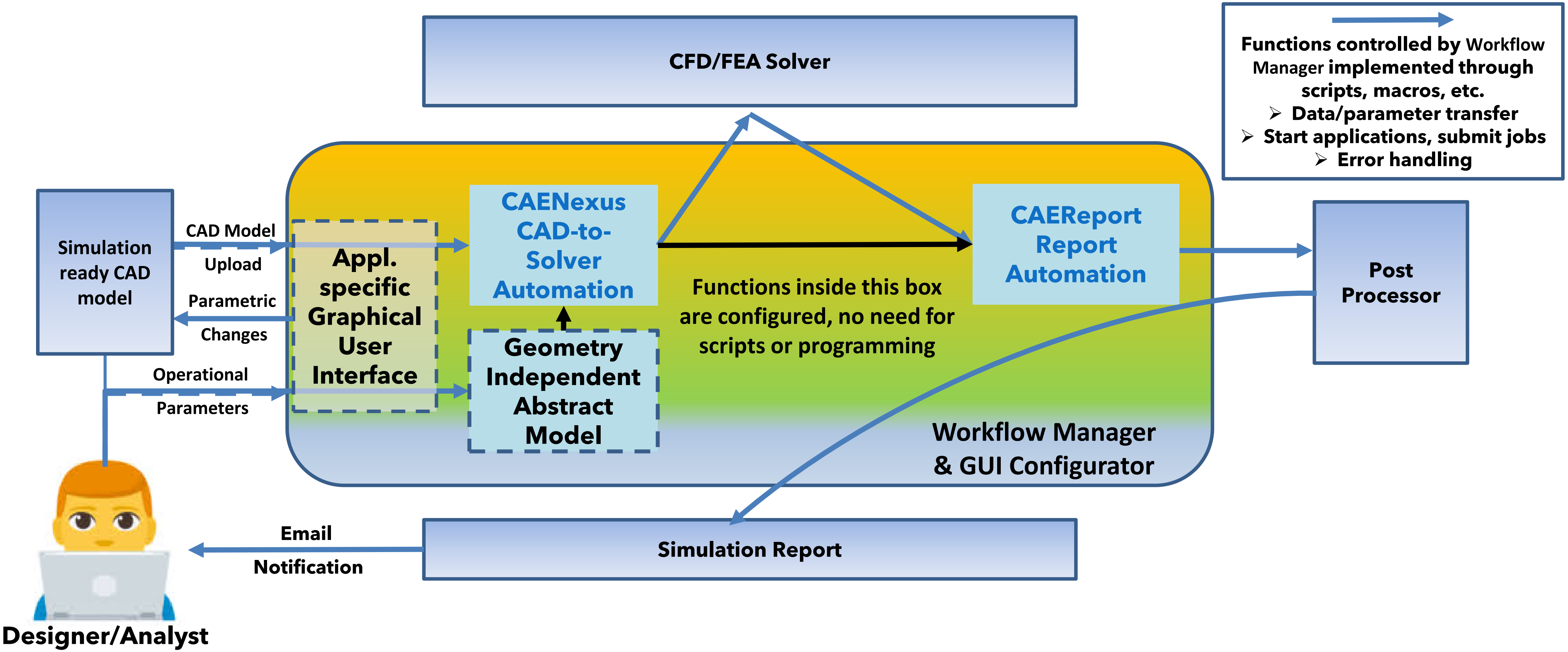
Universal Low-Code Tool Only



Special Low-Code solution for CAD-Solver process and Report Generation needed

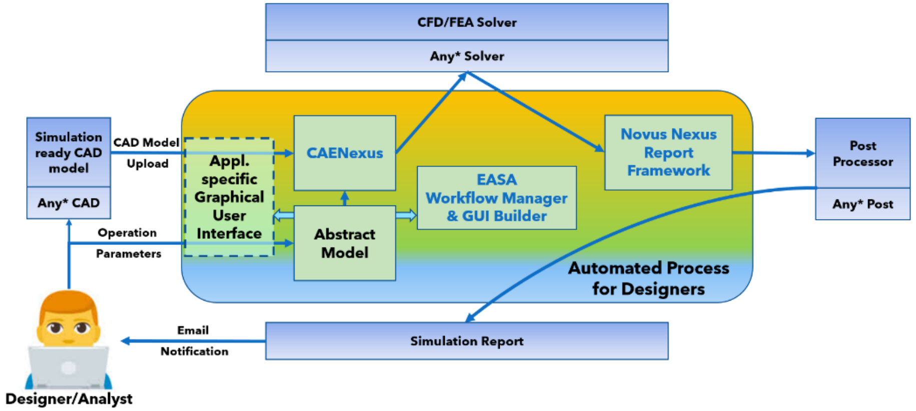
Automated Simulation Process

Simplify with addition of Simulation-specific Low-Code tools



The Less Difficult Path to More Simulation

- Automation carried out with low-code tools
  - Easier and faster to implement and maintain robust automation
    - Configure instead of writing complex scripts
- Combination of universal and simulation specific low-code tools delivers best results
  - Universal
    - Workflow management
    - GUI configuration
  - Simulation specific
    - Configuration of CAD-to-solver process
    - Configuration of report content
    - Re-use best practices, analyst know-how



- Empowers designers to reliably run simulations for **any** geometry
  - Highly complex or greatly varying

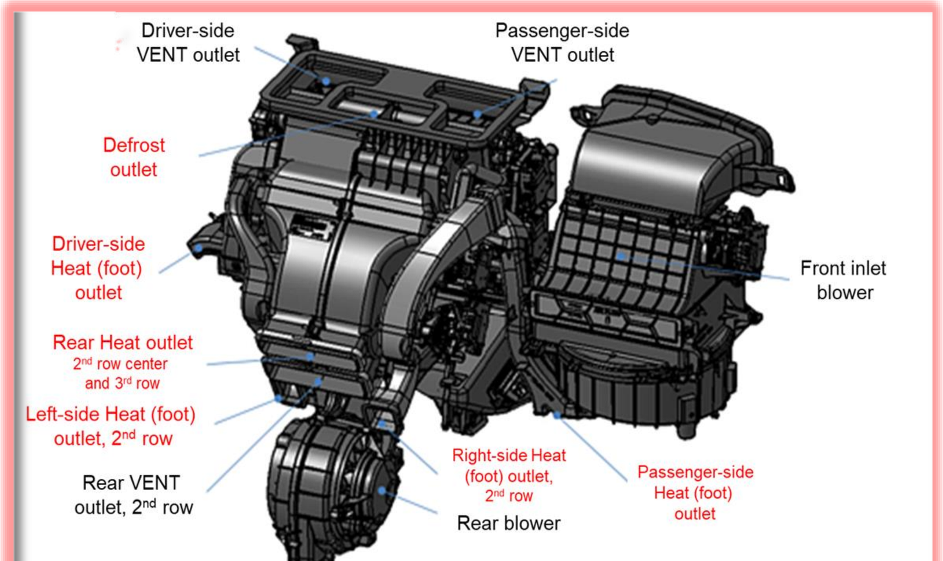
USE CASES

Demo Processes

- CFD Simulation - Automotive HVAC System
- Structural Simulation – Heavy Equipment

Use Case Automotive HVAC Systems

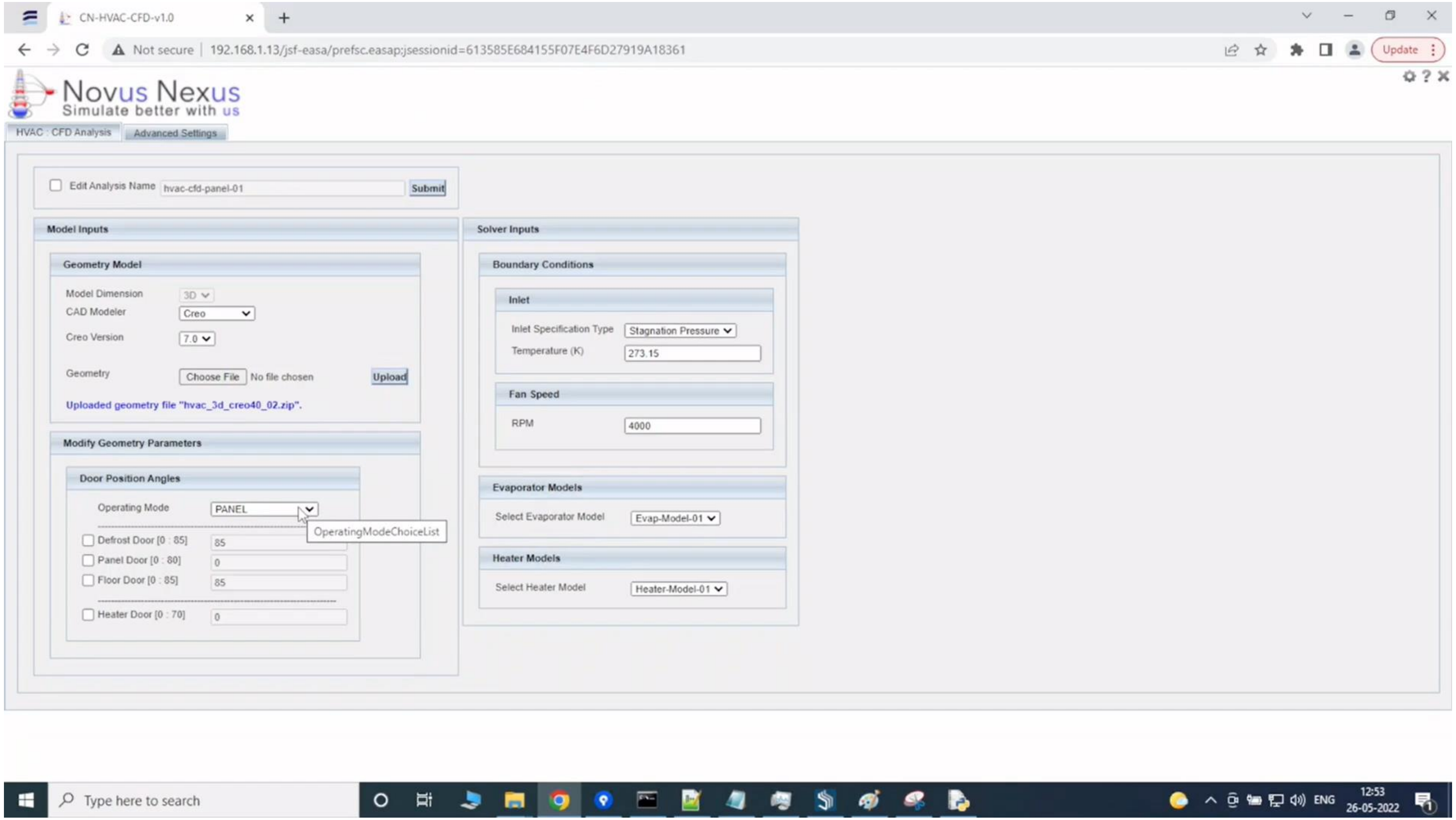
Automation of HVAC CFD Simulation Process



Automotive HVAC Example
Illustration only.

Customer Challenges

- Requirement to significantly increase the number of simulations
  - Customers (OEMs) now want product performance insights already at time of proposal
  - Not enough analysts available
  - Impossible to always perform dependable simulations in time with existing approach
- No in-house resources nor know-how to create a robust automated simulation process
  - Complex geometries and simulation/physics
- Need to ensure that simulation results are always comparable
  - Independent of who, when, and where
- Want ability to preserve simulation know-how when analyst leaves



GUI

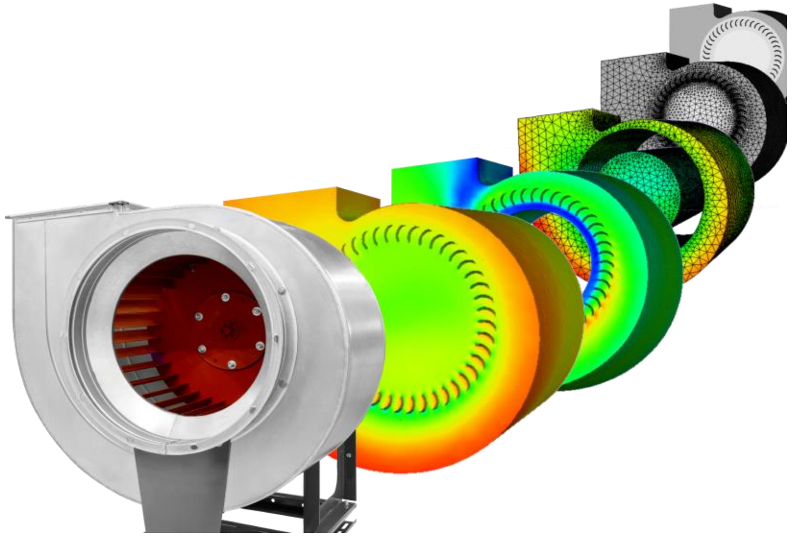
Browser based

- No client installation necessary
- Configured using standard EASA functionality

Implementation Effort

- Extra CAD effort (tagging)
  - 1 hr. initial model, 0 to some minutes follow on models
- Abstract model configuration
  - Pre-processing – 1 day*
  - Report – 1 day*

    * if AM is authored from scratch; starting from similar existing models can reduce time to less than one hour
- GUI configuration – 1 day
- Workflow configuration
  - Misc. scripts, macros, batch commands – 1 ½ days
- Additional testing – 1 day
- Total effort < 6 person days (implementation only, does not include time needed for requirement definition, simulation validation, and other planning/coordination tasks)



Use Case Heavy Equipment

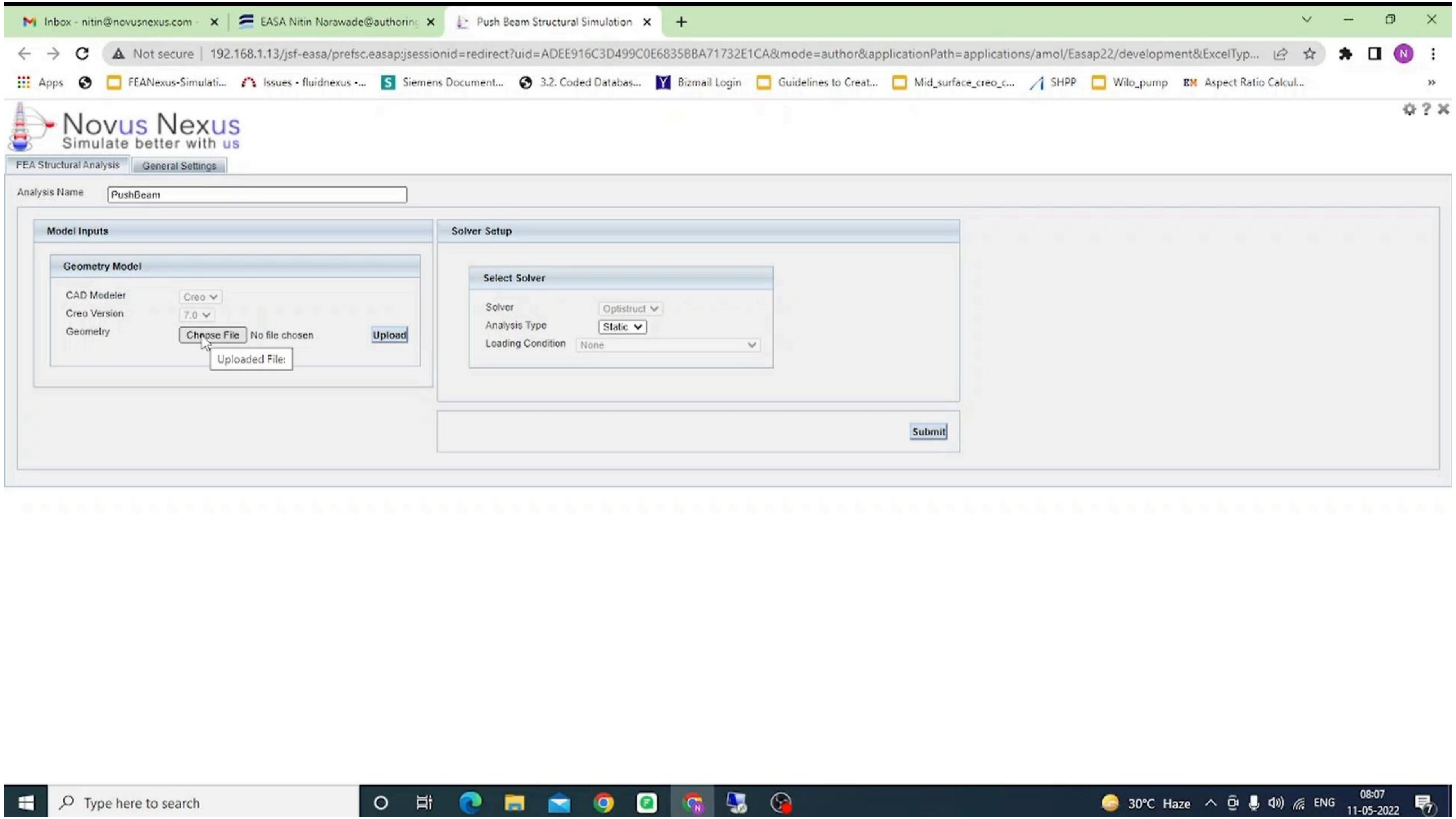
Automation of Structural Simulation Process

User Challenges

- Enable designers to perform dependable simulations
  - — Use simulations systematically for all designs
  - — Ensure that simulations done by designers are applying best practices involving the same tools as used by analysts
- Reliably handle highly complex and vastly varying geometries
- Workflow independent of specific solvers

Solution Implemented

- Automated simulation process for designers
  - — Common end-to-end process and UI for multiple solvers
    - Multiple solvers, geometry types, load cases
  - — Ensures that simulation results are always comparable
  - — In-house team (analysts) created and maintain abstract models and overall automation workflow



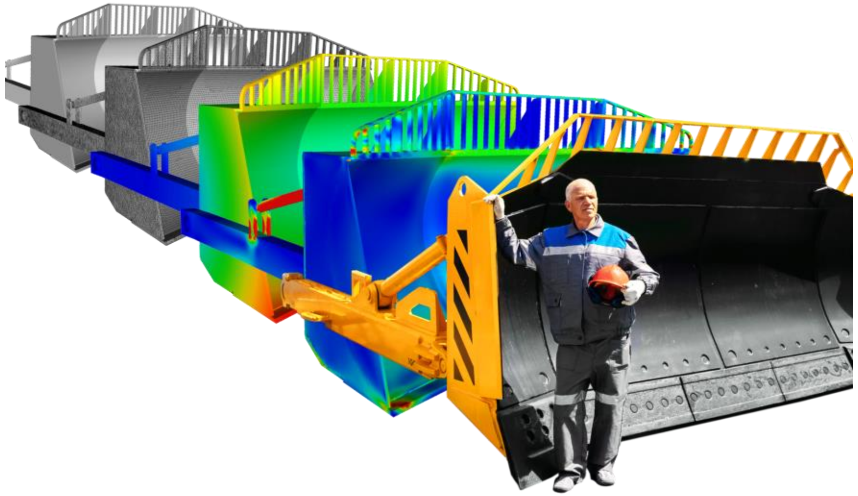
GUI

Physics oriented

- Adapts to CAD model type
- Loads selected for different model types and operational conditions

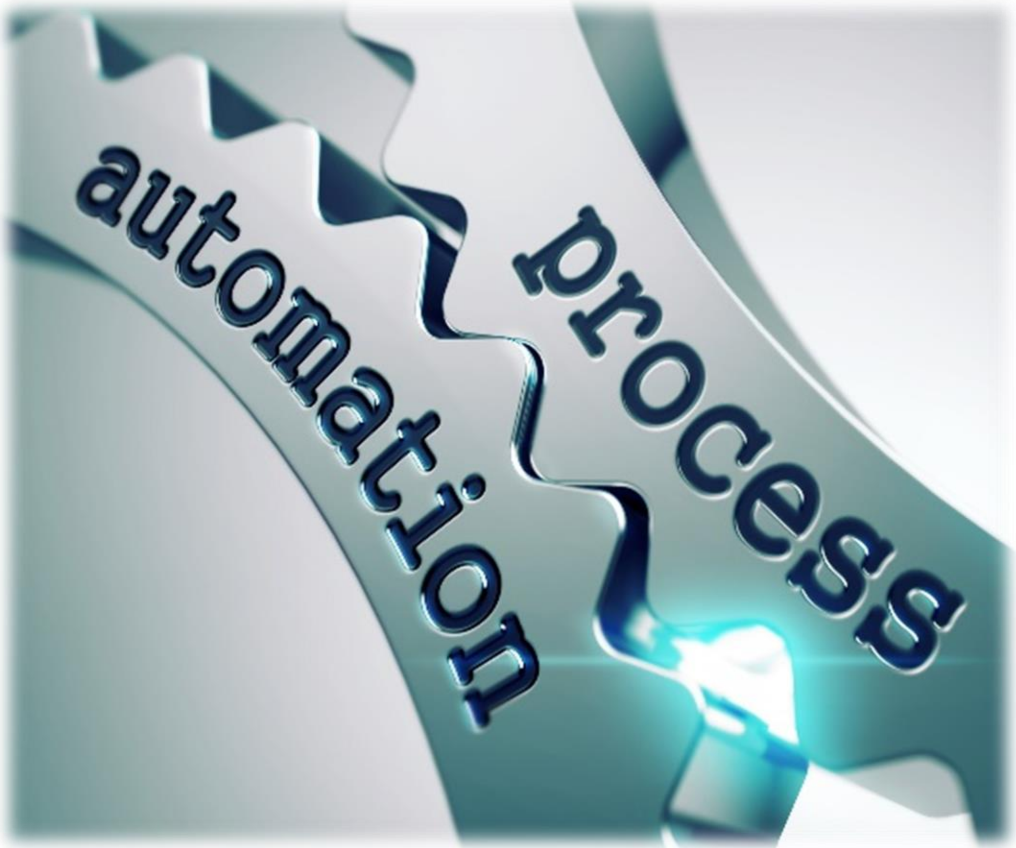
Implementation Effort

- Extra CAD effort (tagging)
  — 20 min. initial model, 0 to 20 minutes follow on models
- Abstract model configuration – total under 1 hour
  — AM is authored from a similar, already existing model
- GUI configuration – 1 day
- Workflow configuration
  — Misc. scripts, macros, batch commands – 1 day
- Additional testing – 1 day
- Total effort < 4 person days (implementation only, does not include time needed for requirement definition, simulation validation, and other planning/coordination tasks)



Summary

- The addition of a **simulation-specific low-code tool** together with universal low-code tool allows practical and economical **simulation processes automation and democratization**
  - Significantly reduces both initial effort and maintenance
- **Geometry independence** is the key
  - "Abstract Models", reusable, geometry independent simulation templates, facilitate automating without extra effort
- **Automation is affordable** for any size company



THANK YOU! QUESTIONS?

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More info about abstract modeling: www.novusnexus.com

Automate Simulation Processes Easily, Quickly and Reliably with Low-Code Tools - Benefits from Systematic use of Simulation

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Davis Evans (Business Development, Novus Nexus, Inc.)

Karlheinz Peters (CEO, CrossoverSolutions, LLC)

Abstract

In order to meet the growing challenges of global competition, the intensive use of simulations in all phases of the product life cycle is becoming increasingly important. Simulation not only helps to develop competitive products faster, but also to accompany and optimize their use.

However, the full achievable benefits of simulation can only be realized when **systematic and efficient simulation** are used. This requires, among other things, that simulation be directly available to a larger user group, and that collaboration between designers and analysts be more closely integrated.

Automated processes for analysts and "end-to-end" simulation applications for designers and product developers are a prerequisite for the systematic and efficient use of simulation. However, the effort required to implement such automated processes often stands in the way of its broader use. In the case of complex, widely differing geometries in particular, the effort quickly becomes prohibitive when using common automation approaches such as extensive (Python, etc.) programming. However, it is not just the initial implementation that is complex in thse cases, but also any later extensions and/or modifications, which sometimes even necessitate the desired automation to be re-created from scratch.

The path to greater benefit from simulation therefore requires new approaches that enable fast, simple and robust process automation. A combination of simulation-specific (e.g. based on abstract modeling) and universal "low-code" tools can drastically simplify automation, even and especially for complex products. Based on example projects, it becomes clear that the necessary implementation effort leads to a good ROI even for simulations with lower repetition rates. Additional benefits of this automation include, but are not limited to, initiation of reliable simulations by non-CAE/CFD specialists, freeing analysts from unproductive routine work, continued use of best practices, and retention of simulation expertise and know-how.

1 The challenge of automating simulation processes

The web portal Digital Engineering 247 interviewed several industry veterans for an analysis [1] of how the use of simulation can be improved and made accessible to a broader user group. They named the automation of simulation processes as the most important factor for broader use. At the same time, it was pointed out that it is often too difficult to implement this reliably and with reasonable effort using standard tools.

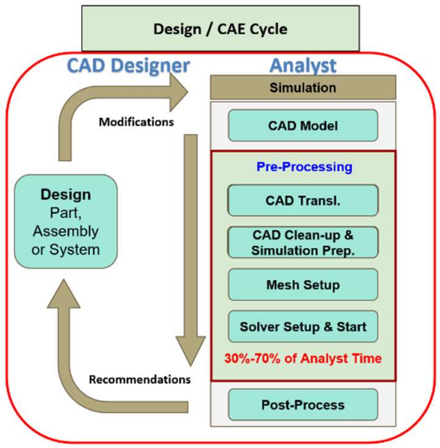

Figure 1: Simulation starting with CAD model

Under these conditions, it is therefore no surprise that, to this day, it is mainly large companies carrying out extremely large numbers of similar simulations who benefit from the advantages of simulation process automation. However, it is astonishing when, at a small research company, PAX Scientific, which only employs one CFD calculation engineer and one CAD engineer, every CFD simulation is started by an automatic process (CAD-to-solver input files/mesh) [2]. What is happening differently there, how is this small team able to automate all projects efficiently without great effort?

1.1 First geometry, then simulation and simulation approach

Common preprocessors first expect a geometry, to which all simulation parameters, e.g. material data, loads, specifications for mesh generation, etc., are then added. This is appropriate for analysts who work interactively with the preprocessor; they see the current model to be simulated with all the details and can take them into account accordingly.

However, this procedure is less suitable for automatic processes. The programming (scripts) must anticipate what geometry variations could possibly occur, and then add the simulation parameters in the correct places. However, this is often not possible or would limit innovation. In the case of complex geometries, this approach often reaches its limits.

For varying CAD models that change within foreseeable limits, it is true that automation using common preprocessors may be feasible within reasonable effort. But the situation quickly becomes unwieldy when CAD model geometries vary greatly or are very complex.

The dependency on explicit existing geometries explains why the automation of simulation processes is often a challenge. But are there also ways to overcome these challenges?

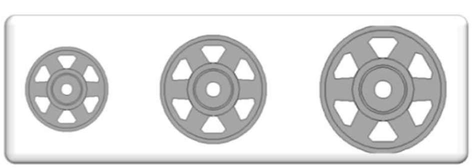

Figure 2: geometries with foreseeable changes

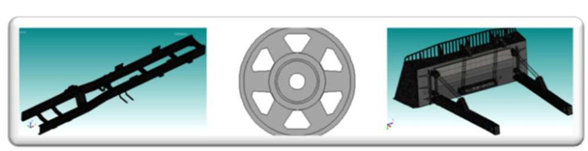

Figure 3: geometries with unforeseeable changes

1.2 Geometry-independent specification of the simulation

The way practiced at PAX Scientific overcomes the geometry dependency by using geometry-independent simulation templates that can be reused for any CAD model. These templates, so-called "abstract models", do not apply simulation parameters directly to a geometry, but use classes (3D, 2D, 1D) as placeholders. Also, CAD models to be analyzed are supplemented with complementary text attributes. This allows a preprocessor based on this abstract modeling approach to attach all simulation parameters to the correct solids, surfaces, etc. and automatically generate the files necessary for the solver, including mesh. To start the automated CAD-to-Solver process, all one needs is a batch command that specifies which CAD model is to be combined with which abstract model and in which folder the generated solver files are to be stored.

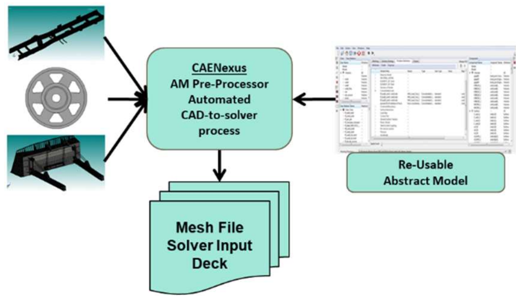

Figure 4: Automatic CAD-to-Solver process for arbitrary geometries

The use of abstract modeling enables PAX to automate any new CFD simulation application by configuring an appropriate template (CAD-to-solver) in less than an hour. In the future, there are also plans to configure and automatically create all reports using abstract models. The CAE company that develops the preprocessor used at PAX is in the process of releasing an add-on module for report generation, which is currently being tested.

2 Automation of simulation processes - efficiency through low-code tools

Universal low-code tools offer the possibility to quickly create software applications by configuring user interfaces and workflows. This greatly reduces the programming and scripting that would otherwise be required. Functionality that is configured in a browser-based GUI for example is easier to understand and modify than that implemented through programming. But the name "Low-Code Tools" gives it away: programs, scripts, macros, etc. are still necessary to address the SW applications involved, to process data, etc.

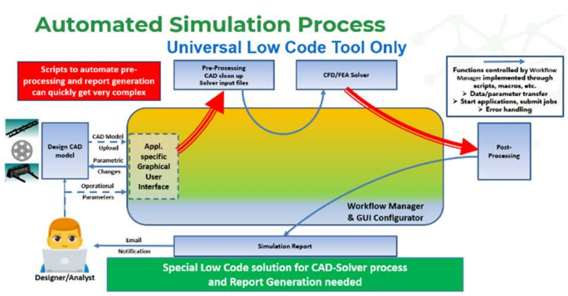

Figure 5: Automation with universal low-code tool

If you automate simulation processes using universal low-code tools, batch commands for starting the solver, for example, can be implemented relatively easily. The tool just needs to know where to put the input files and mesh, and where to put the results. A script for preparing the geometry and creating all the solver input files, on the other hand, can quickly become very complex and inflexible. The same applies to report generation.

As PAX shows, a preprocessor working with abstract modeling can automate the CAD-to-solver process (soon to include reporting) simply by configuring an abstract model. The preprocessor used at PAX largely replaces programming with configuration, and so operates like a simulation-specific low-code tool.

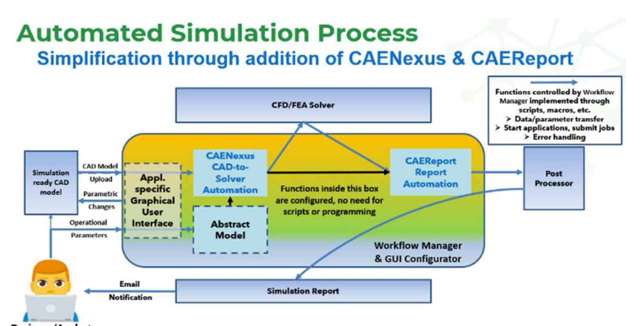

Figure 6: Simplified automation by combining low-code tools

If you combine universal with simulation-specific low-code tools, end-to-end automation becomes practicable even for complex simulation processes, as the required programming effort is drastically reduced. Figure 6 shows the changed approach with avoidance of the problematic programming aspects. An important difference in the process with abstract models is that CAD models are prepared for simulation, the aforementioned text attributes are attached and e.g. in CFD the fluid space is modeled.

3 Effort examples

Users of an abstract model-based preprocessor can implement such simulation automation across a wide range of processes, including for example, the design of vehicle air conditioning systems (HVAC) or structural analysis of heavy equipment for construction, agriculture and forestry. The company Novus Nexus, creator of the preprocessor used at PAX, CAENexus, has created automated sample processes for such applications, which can be quickly converted to other customer requirements as part of pilot projects (CFD and FEA).

The range of functions gained from marrying universal and simulation-specific low-code tools includes browser-based, application-specific user interfaces with options for geometry changes for different use conditions, automatic creation of the solver input files, easy start of varied simulations, automatic report creation and notification when reports are ready.

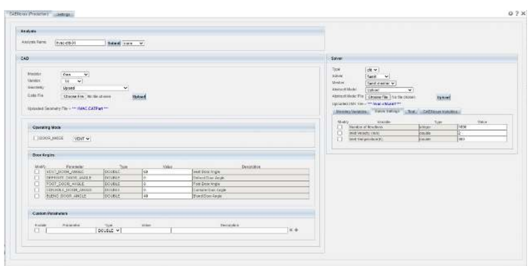

Figure 7: GUI HVAC system

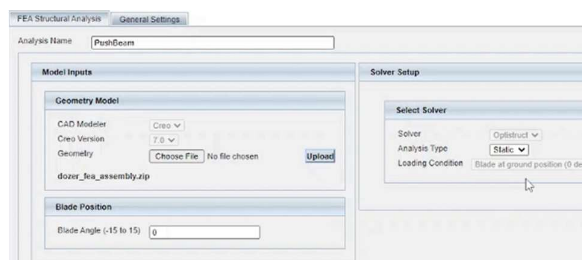

Figure 8: GUI structure analysis

The following table shows the net times for creating the two automated processes. It is assumed that preparations such as the definition of the GUI interactions, clarification of the simulation procedure (best practices) and determination of the CAD parameters that can be changed by the process or boundary conditions for the simulation have been completed.

Table 1: Comparing Automated Process Implementation Efforts

Task	HVAC	Stucture Analysis
CAD Preparation - Text Strings		
First Model	1 h	20 min
Model Variations	0 - 20 min	0 - 20 min
Configuration of Abstract Model		
Pre-Processing	8 h	1 h
Report	8 h	1 h
Universal Low-Code Tool		
GUI Configuration	8 h	8 h
Workflow	12 h	8 h
System Tests	8 h	8 h
Total Effort	5 - 6 days	< 4 days

Note: The abstract model for HVAC was created from scratch, an existing model was adapted for the structural analysis

The user interfaces in the examples shown here offer fewer options than the applications currently used by customers. However, the effort for such extended interactions is usually only a few additional hours or days due to the configuration options.

4 Conclusions

The above examples and in particular the practice at PAX Scientific show that the automation of simulation processes using low-code tools can be implemented efficiently, economically and reliably, even for complex products. Abstract modeling-based solutions provide the approach needed to easily overcome the biggest challenges in automation: CAD-to-solver processes and report generation.

The described combination of simulation-specific and universal "low-code" tools offers the new, easier way to the advantages of automation. Democratization of simulation, relieving analysts of unproductive routine work, continuous use of best practices and the preservation of simulation knowledge make product development more efficient and thereby increase the competitiveness of manufacturers.

5 References

[1] B. Albright, “Democratization of Simulation Software,” *Digital Engineering*, Sep. 01, 2019. https://www.digitalengineering247.com/article/the-path-to-simulation/

[2] “Fast and Easy Simulation Automation Accelerates Innovation at PAX Scientific for US Navy and Others,” *Revolution In Simulation,* June, 2022. https://revolutioninsimulation.org/webinar/fast-and-easy-simulation-automation-accelerates-innovation-at-pax-scientific-for-us-navy-and-others