



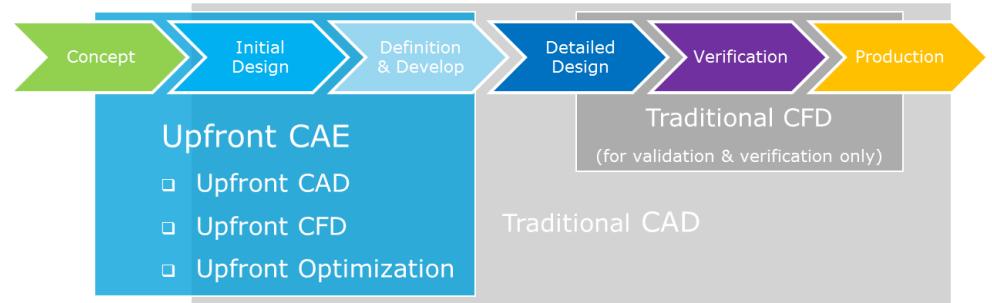
## Software for CFD-driven parametric shape optimization

CAESES<sup>®</sup> is the industry standard for the simulation-driven design of complex freeform surfaces. When designing components or products featuring performance critical shapes, such as turbomachinery blades, ship hulls, or engine components, CAESES<sup>®</sup> is the ideal modeling, integration and automation framework for maximizing analysis throughput. CAESES<sup>®</sup> is an “Upfront CAE” system that empowers engineers to achieve product designs that have the very best in class performance. CAESES<sup>®</sup> breaks the rules of traditional product development and unleashes design innovation.

### A comprehensive Upfront CAE system

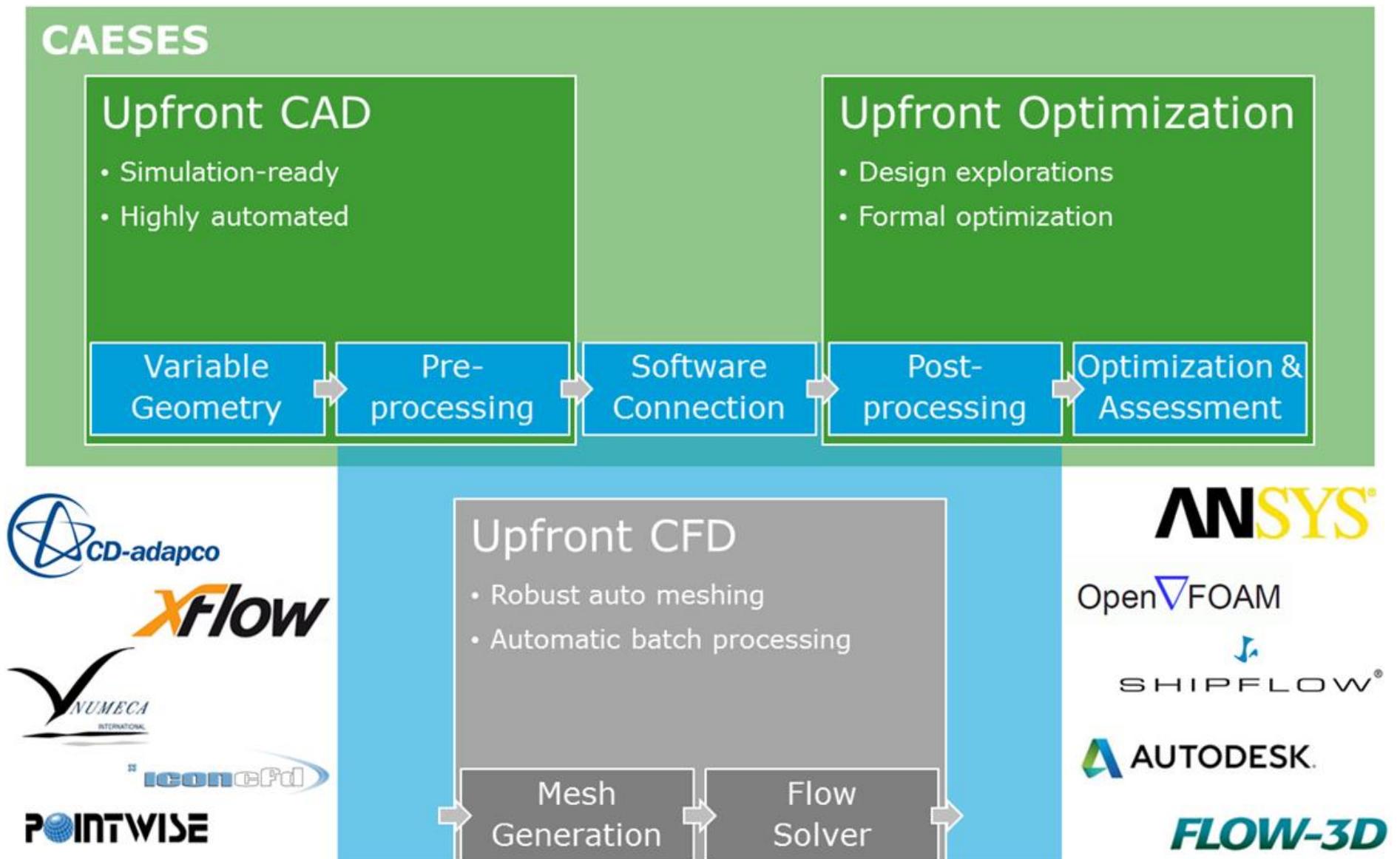
CAESES stands for “CAE system empowering simulation” and its ultimate goal is to enable engineers to design optimal products. With CAESES as the *Upfront CAE* workhorse, engineers can explore a multitude of design variants within highly automated workflows. This empowers users to either optimize existing designs by squeezing out the last few efficiency points, or to explore novel and innovative concepts that blow away old paradigms.

The best opportunity for design explorations and shape variations is early-on within the product development cycle, before designs become too rigid and constrained, and large changes are disruptive. This is the time when enough freedom remains to creatively explore innovative designs. CAESES is the only dedicated *Upfront CAE* system that makes this possible within an efficient and totally automated process.



CAESES is a complete integration framework that provides ready-for-analysis geometry with the *Upfront CAD* modeler, a software connector to tightly couple with commercial, open source, or in-house CFD tools, as well as an *Upfront Optimization* module, all in one package. The typical workflow to set up the automation process comprises of our “big 5” steps: variable geometry, pre-processing, software connection, post-processing, and optimization & assessment.

Upfront CAE with CAESES, the complete integration package for simulation driven design and shape optimization.



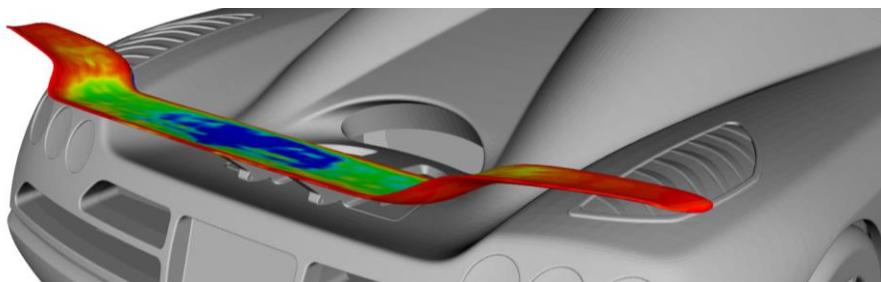
### Upfront CAD for variable geometry modeling

Shape optimization is widely talked about in CFD circles, but for complex shapes, automated geometry variation is either error prone or simply untenable. Furthermore, relying on the CAD department, whose models are typically detail-centric, is a major barrier to maximizing your CFD analysis throughput.

CAESES breaks down these barriers with its *Upfront CAD* modeler making automated optimization workflows a reality. Our modeler is based on in-house proprietary technology and we specialize in creating high-fidelity variable geometry models of complex freeform shapes, ready to go for analysis. Bringing the right amount of detail at the right time to your CFD tool is critical in achieving design explorations when they're needed – Upfront!

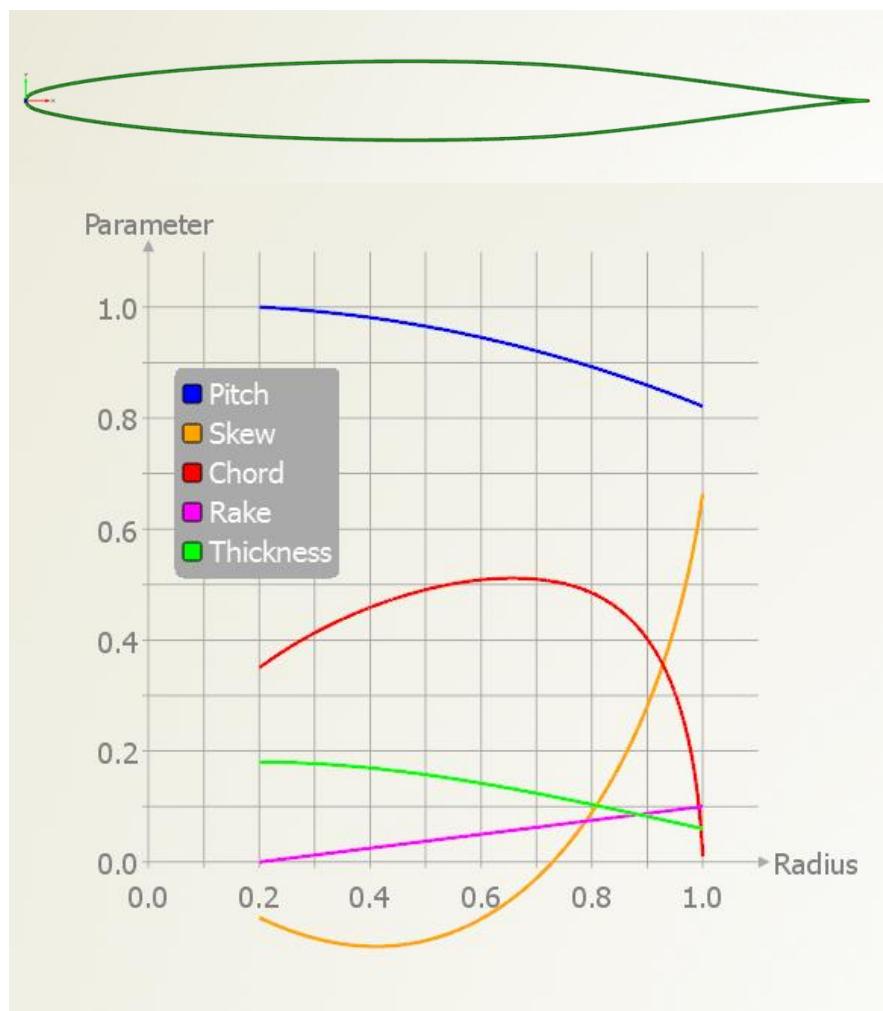
Our modeler includes a large library of curve and surface types. In particular, our proprietary surface modeling technology allows users to define complex surfaces with fewer design variables, leading to more efficient design studies. We can also build constraints right into the model so that all of the automatically created shape variants meet your criteria and you do not waste time creating and analyzing infeasible designs.

For optimization studies using adjoint CFD, we even have specialized parametric sensitivity capabilities that are able to use the adjoint sensitivity results to directly modify the parameterized model in ways that make sense (e.g. for manufacturing).

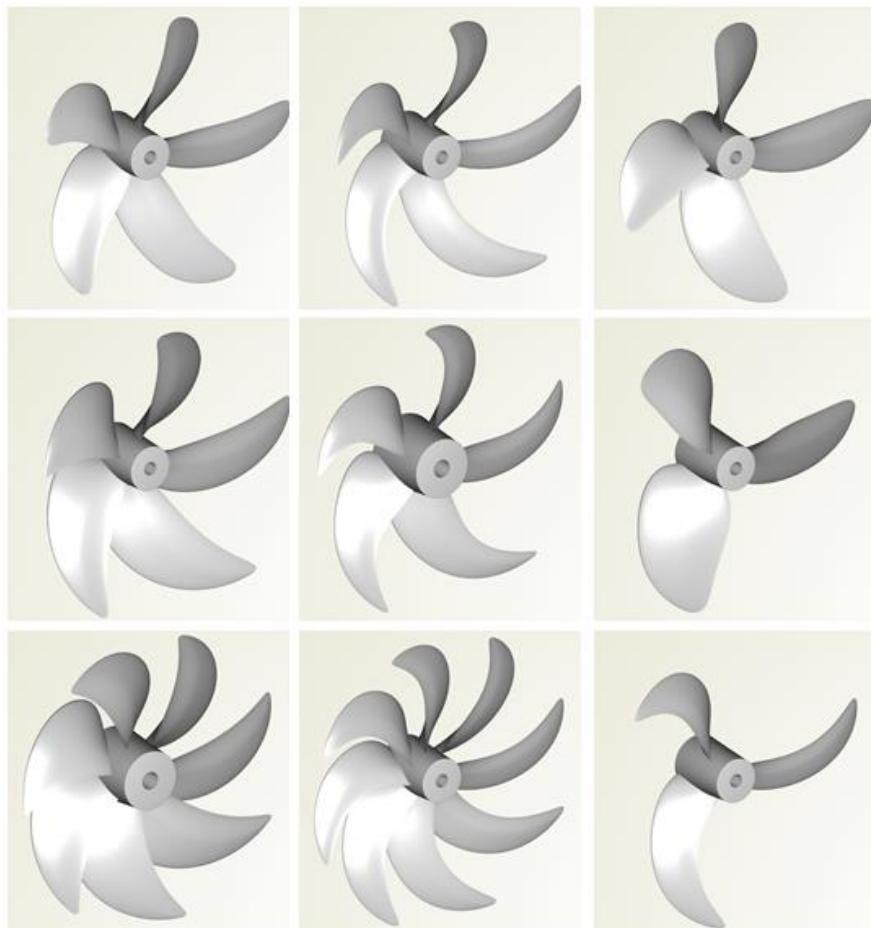


“In our experience, using CAESES for creating parametric models was MUCH faster and easier than with our traditional CAD tool. With CAESES we can now create all of the design candidates in hours instead of weeks!”

Pol Muller, Head of Thrusters, DCNS Research



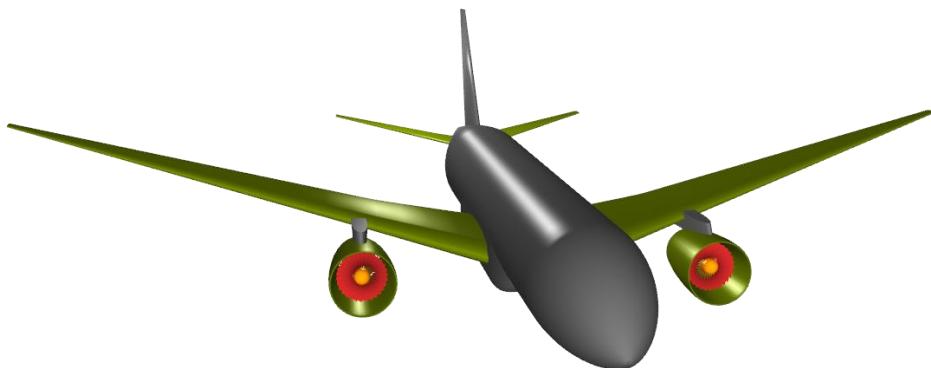
From 2D thinking to 3D shapes: A propeller parameterized in the 2D section with functional definitions in the radial direction.



A single model created in CAESES can be used to create a family of diverse design variants, ready for analysis.

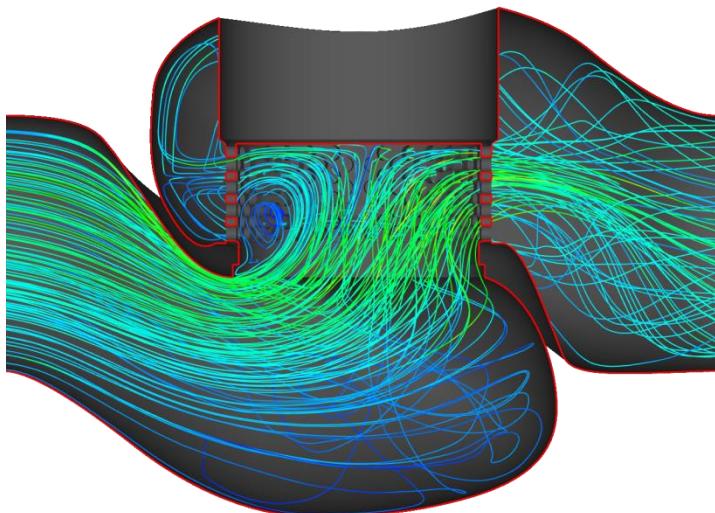
### Robust and accurate pre-processing

To run a seamless automation you need to provide geometry that the CFD and meshing tools can understand. CAESES provides many exchange formats including specialized outputs that are custom tailored for some of the most popular CFD codes. On top of that, to ensure that the process does not break down, the models have to be robust during the variations studies. CAESES includes adaptation and healing tools that guarantee high-fidelity models which are always watertight, even when investigating topological changes.



### Coupling to simulation software

CAESES has a software connector that makes coupling to CFD solvers, grid generators, and other analysis tools easy and intuitive. The user just needs to set up the control files that are used to launch the solver in batch mode. These files can include parameters that are edited by CAESES as part of the study. So in addition to geometry variations, other variables can be changed such as boundary conditions (e.g. to include multiple operating conditions), and solver or grid settings (e.g. to test turbulence models, grid independence studies). The outputs from the computation are read back into CAESES and used by the optimization algorithms to create additional designs as part of the variation and optimization study.



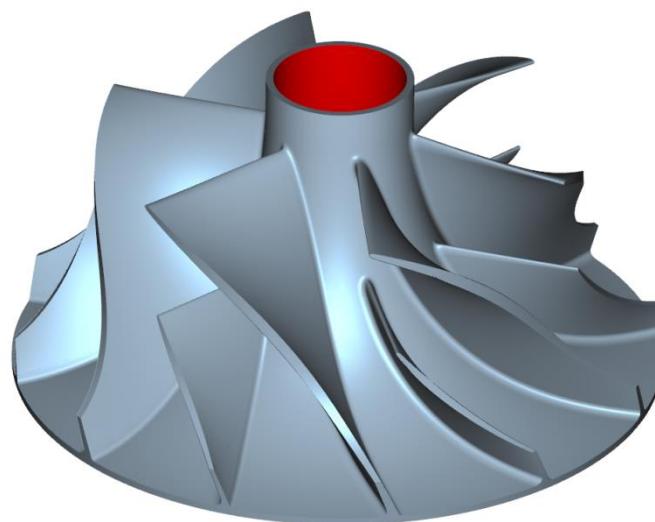
### Post-processing large data sets

CAESES has its own post-processor that can load the CFD flow-field results and visualize them, with an emphasis on enabling a quick overview of the different variants and comparing the most promising design candidates. In addition, screen shots that were created by the external tool can be imported, as well as table data (e.g. convergence history, time series of objective functions).

### Upfront optimization and assessment

If the *Upfront CAD* modeler is the heart of CAESES, then the optimization tools are the brains. All of the previous steps: variable geometry, pre-processing, software connection, and post-processing are prerequisites to set up the automation chain. The design engines and optimization tools are now ready to take the controls. CAESES includes various algorithms such as DoE (e.g. Sobol) and several single-/multi-objective optimization algorithms (e.g. NSGA-II, MOSA). Our own grid engine, the SSH Resource Manager can configure and execute the study on distributed or cloud-based HPC computing. When the computers have completed the heavy lifting, the interesting work can begin. CAESES includes various convenient ways of analyzing large data sets including design tables for sorting and ranking, result analytics, and automatic report creation (e.g. spider-web plots, Pareto frontier plots).

CAESES empowers engineers to leverage their CFD tools to make bold leaps in design innovation and optimization. Design, solve, optimize!



“CAESES is a core component in the design department, and nowadays it drives all new product developments to ensure the very best performance.”

David Bendl, Development Engineer, VOITH