Suqaba: Reshaping Simulation Software

In industries such as transportation, defense, or healthcare, computer technology is widely employed to virtually test products from the earliest stages of design. These tests are conducted using simulation software (see Figure 1), which replicates real-world conditions, to evaluate performance, safety, and durability before manufacturing begins. However, these methods inevitably introduce *errors* when compared to reality. This raises a fundamental question: how much can we trust in the results provided by these simulations? In pursuit of reliable simulations, Suqaba has developed an innovative standard built entirely on error quantification and its control.

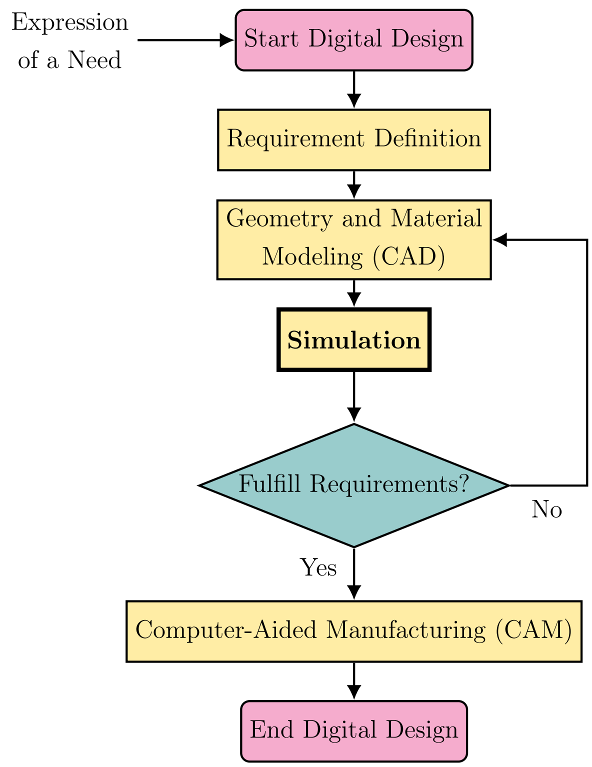


Figure 1: Flowchart of the Digital Design Process

Despite the widespread adoption of digital simulation in design offices, no existing software provides rigorous result verification and certification. Currently, simulation outputs are visualized using color maps, representing variables such as forces and temperatures. However, these visualizations offer no insight into the accuracy of the results or the confidence level associated with them. Yet, critical decisions are made based on these outputs, with a major impact on the subsequent phases of the design cycle. It is therefore critical to introduce reliable certification mechanisms within simulation software.

Suqaba stands apart from existing software by integrating innovative methods designed to quantify and reduce the error (see Figure 2). Controlling simulation errors unlocks new possibilities:

- **Increased confidence in results**: Users can assess the reliability of results or quantify and mitigate potential risks;

- **Intelligent model analysis**: The simulation is automatically optimized to improve quality where needed, focusing computational power on critical areas, thereby reducing simulation time;

- **Optimal management of computing resources**: Computational effort is adapted according to error levels, ensuring efficient use of available resources and increasing energy efficiency.

This also eliminates the challenges associated with manually configuring simulations. By specifying an error requirement, the user gets reliable results with local error indicators that show confidence levels, for a well-informed decision-making. Not only does this technological foundation automate simulations, but it also redefines human-machine interaction.

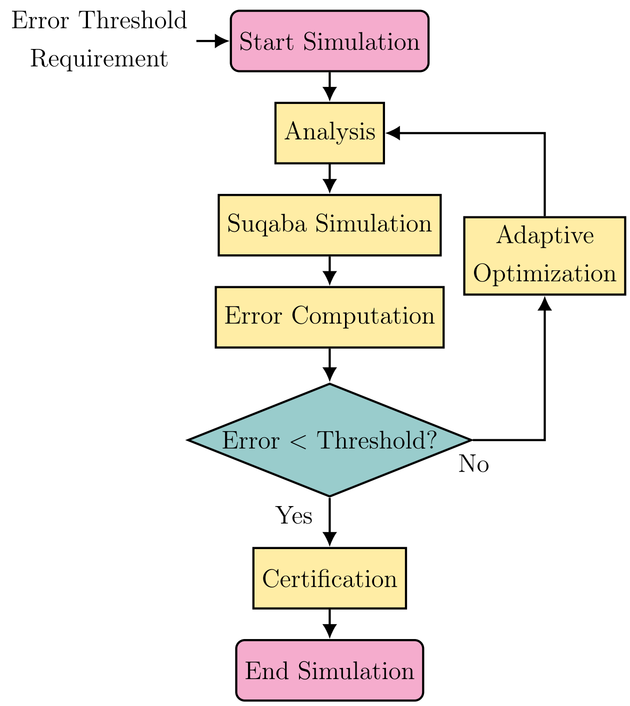


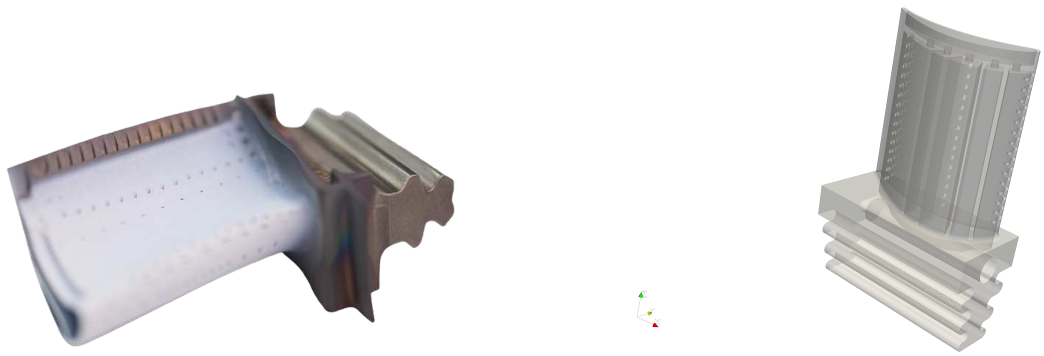
Figure 2: Flowchart of the Suqaba Standard for Simulation

Our technology has been validated on relevant industrial cases. The simulation of a high-pressure turbine blade with an internal cooling system is presented as an example (see Figures 3a and 3b). Simulating this component is critical as its mechanical behavior directly impacts the safety and performance (thrust, fuel consumption, etc.) of turbofan engines. Initially, the error is 20.2%, but by the end of the simulation, it drops to 0.98% (see Figures 4, 5, and 6). Early in the simulation, high errors are found in the red areas, indicating low quality. The simulation automatically optimizes these areas, and by the end, the errors show predominantly blue, indicating an uniformly low error or high quality.

The ultimate goal of the developed technology is to enhance the reliability of digital design, reducing the risk of high costs due to design errors and improving overall product life cycle efficiency. A simulation software is a virtual laboratory in which users carry out experiments they would not be able to implement in real life. Their results drive decision-making, with a major impact on products life cycle. Suqaba makes the standardization and certification of virtual labs its mission.

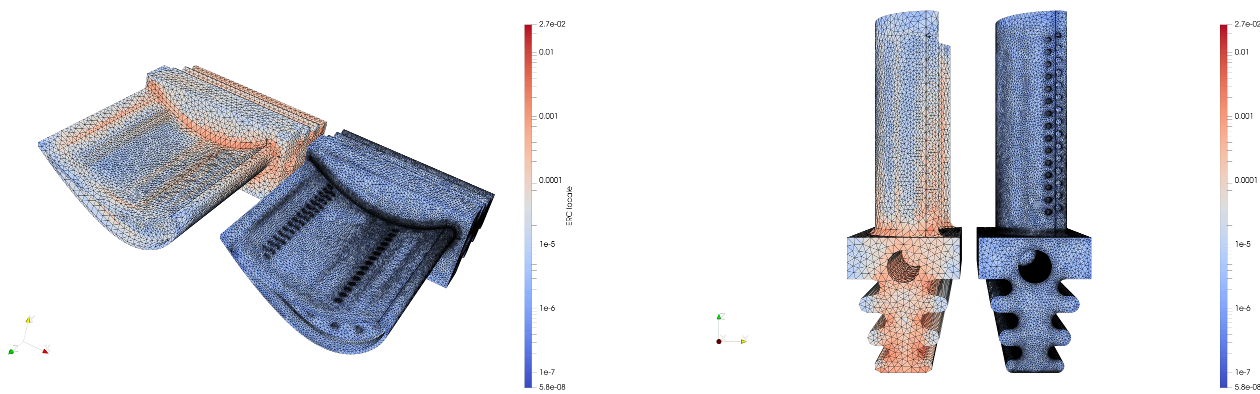
Table 1: Simulation Result for a 1% Error Threshold

	Simulation Initialization	**Simulation Result**
Error (%)	20.2	0.98



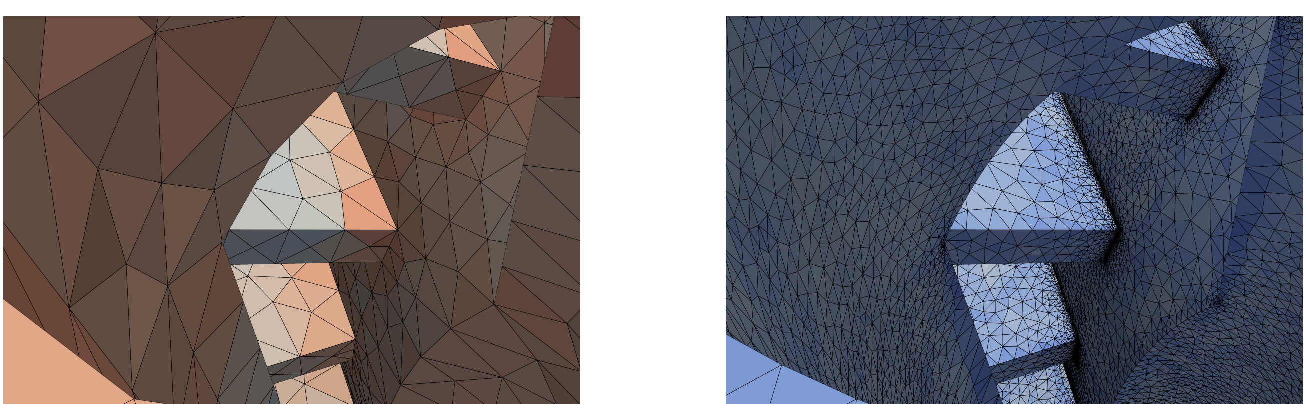
(a) Photograph of the Real Turbine Blade (b) Used CAD Model

Figure 3: High-Pressure Turbine Blade Designed during the CFM56 Program



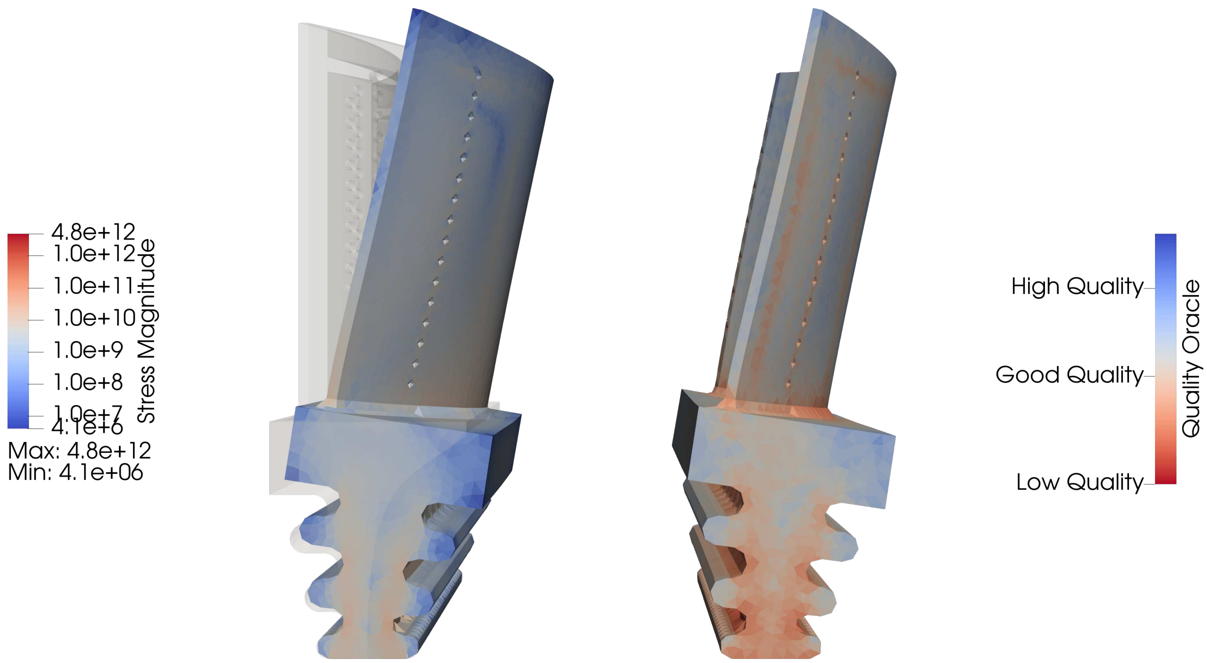
(a) Visualization of the Pressure Surface; Simulation Initialization (left), Simulation Result (right) (b) Leading Edge and Blade Root; Simulation Initialization (left), Simulation Result (right)

Figure 4: Local Error Indicator between Simulation Initialization and Result (red: high error, blue: low error)

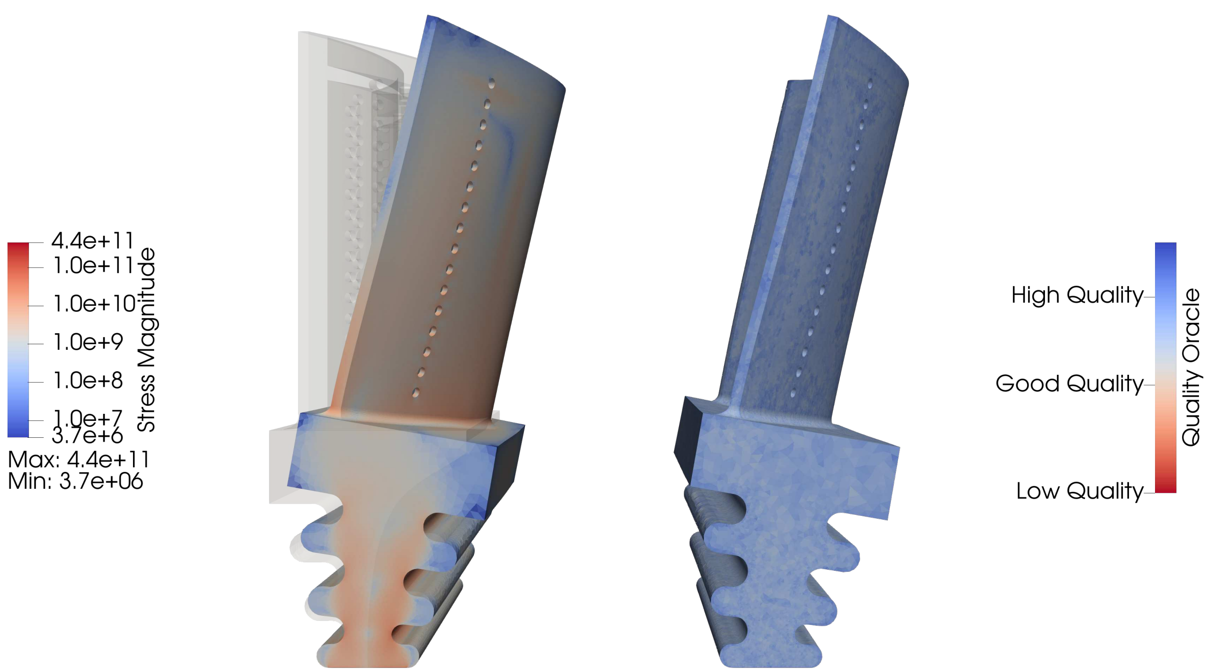


(a) Simulation Initialization (b) Simulation Result

Figure 5: Visualization of the Internal Cooling Circuits (red: high error, blue: low error)



(a) Simulation Initialization



(b) Simulation Result

Figure 6: Left: Visualization of the Deformed Blade and Stress Magnitude (undeformed blade in low opacity); Right: “Quality Oracle”, i.e. Quality/Confidence Indicator.