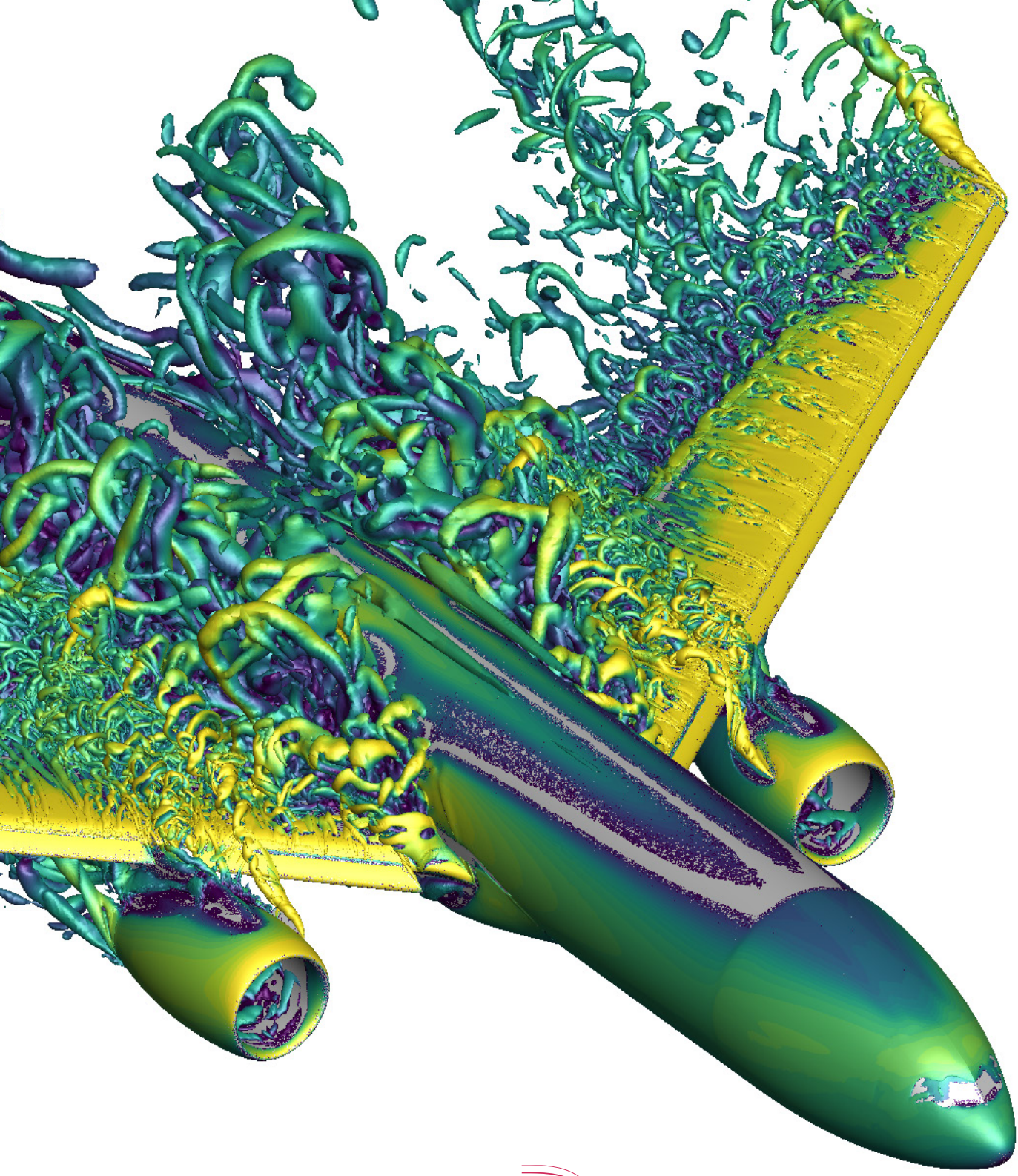


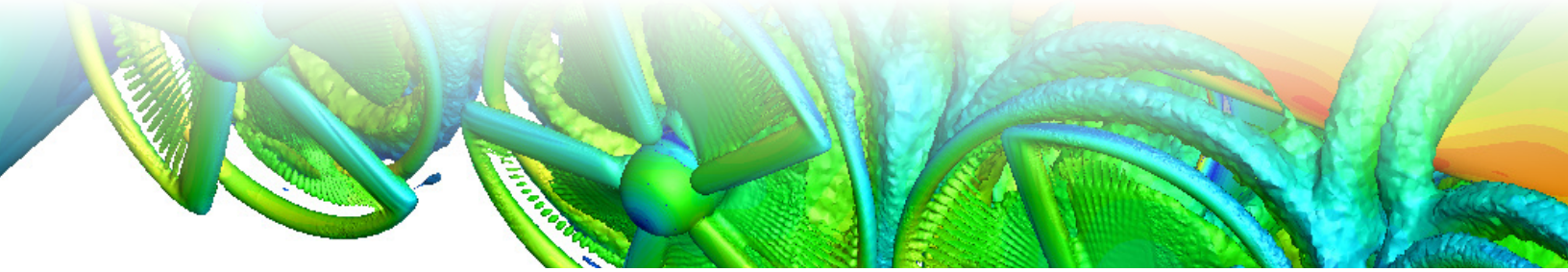
Flow360

Technical Brief

Trends driving the use of CFD

Aerospace design tools are shifting away from experimental methods (wind tunnel tests, small scale models, truck tests, flight tests, etc.) towards virtual simulation based approaches — in particular, computational fluid dynamics (CFD). Thanks to the exponential growth in compute power, CFD is becoming the main aero design tool for most aerospace companies.

By analyzing potential designs virtually, CFD makes it much easier to quickly and thoroughly test all potential improvements without spending time and resources on building any of the intermediate steps. Current CFD tools allow designers to get accurate results for complex flow scenarios much quicker than experimental methods. This is particularly true for eVTOL, supersonic, and hypersonic aircraft for which getting reliable experimental data is particularly complex, expensive, and cumbersome. CFD has become an integral part of the design process because of its ease of use, accuracy, flexibility, and high return on investment.



High accuracy CFD will become an even more important link in the aerospace design toolchain because it is:

1

Cheaper than most experimental alternatives, especially when applied from the very beginning. It allows engineers to virtually stress test designs and catch flaws early in the design cycle.

2

Faster than any other comparable experimental means. With Flexcompute's CFD solutions, engineers can modify a design parameter and get a new high accuracy CFD solution in minutes.

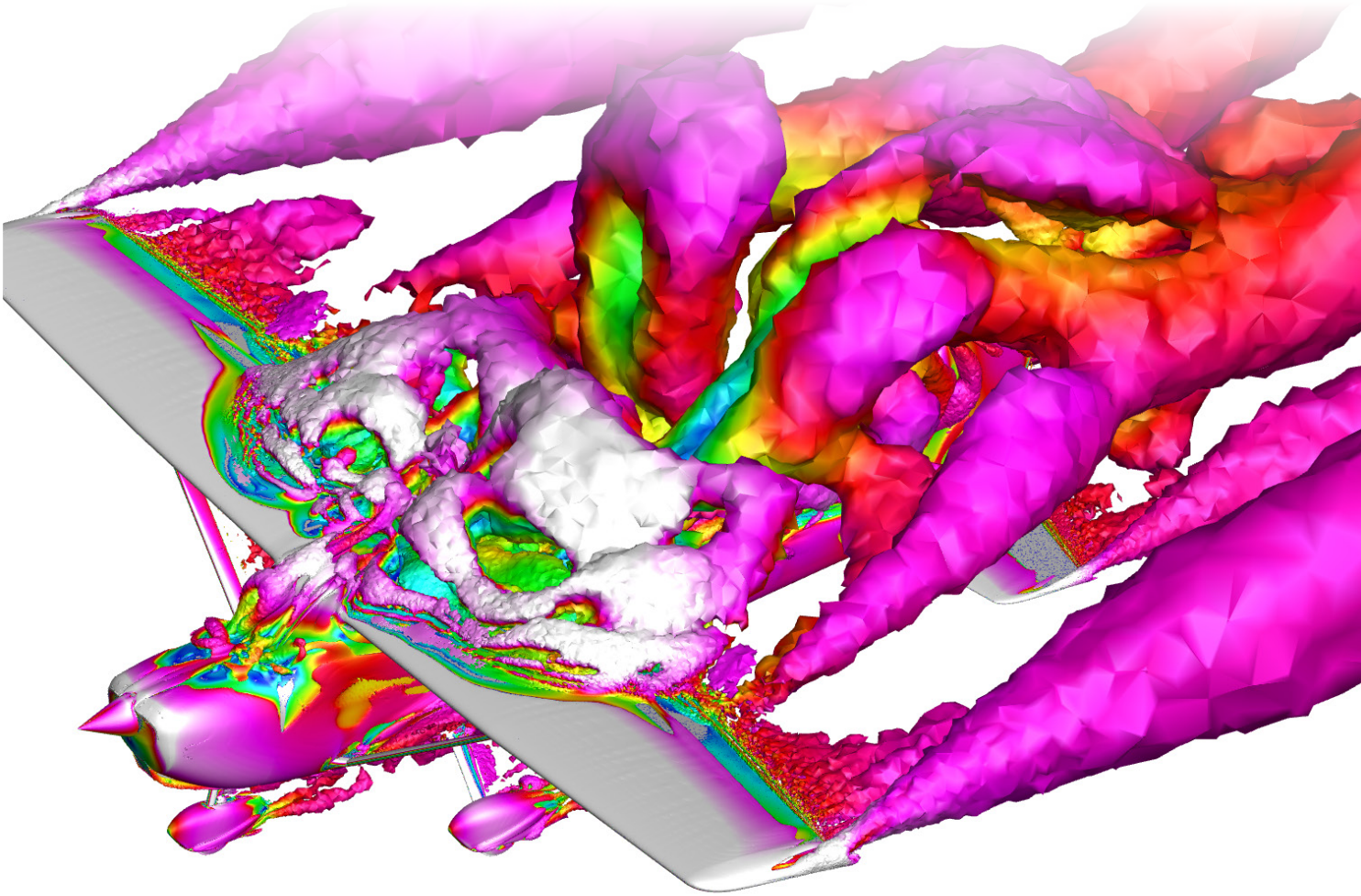
3

Highly flexible; modern CFD solutions, like Flexcompute, allow for flexibility in resources and adapt to varying simulation needs.

4

Highly informative; CFD results give researchers more than just information as to which design is better. CFD allows for investigations into where the differences in performance come from and why a given design is better. With CFD, designers can thoroughly analyze unexpected and/or unsatisfactory behavior and figure out what is going wrong.

All this boils down to the fact that, with high accuracy CFD, aerospace designs will be more thoroughly tested, better optimized, and more predictable. This translates into quicker turnaround times, less risky design decisions, and money saved in both the short and long term.



Current bottlenecks to high accuracy CFD

For any business interested in running high accuracy CFD simulations, accessing state of the art resources was, until recently, a very frustrating endeavor requiring large amounts of time and upfront capital to set up. Many expensive decisions are required relating to software licensing, leasing cloud resources, purchasing on-premise high performance computing (HPC) hardware, and continued maintenance by IT specialists.

The other significant bottleneck to widespread CFD adoption is that CFD run times are still uncomfortably long. While all CFD codes have incrementally become more efficient and HPC resources have become more powerful, the needs of the industry have far outpaced these improvements, leading to constant frustration by CFD engineers who cannot run the level of complexity desired within realistic timeframes.

There is a better way

In 2016 a group of researchers from various universities, led by Prof. Qiqi Wang, started looking at how CFD was traditionally being done and saw many areas for improvement. Shortly thereafter, the Flow360 CFD solver was born. Flexcompute, as a company, quickly followed suit with the goal of commercializing that revolutionary new CFD software.

Whereas most common CFD solutions evolve slowly over time and are hampered by decades of obsolete processes and techniques; by starting from scratch and creating a brand new CFD solution tailored to solving current and future CFD needs, Flexcompute has been able to create a truly improved CFD experience.

Flow360 is based on a full-stack software-hardware design. All aspects of the implementation are tailored and optimized for maximum performance on modern hardware without sacrificing solution accuracy. The result is a CFD solver unrestricted by typical scalability limits that is at least 100s of times faster than conventional CPU-based solvers.

This innovative approach would not be complete without a thorough investigation of cost. By improving efficiencies along the entire pipeline, Flexcompute can now proudly claim that Flow360 is not only faster but more cost effective than any other comparable CFD solution.

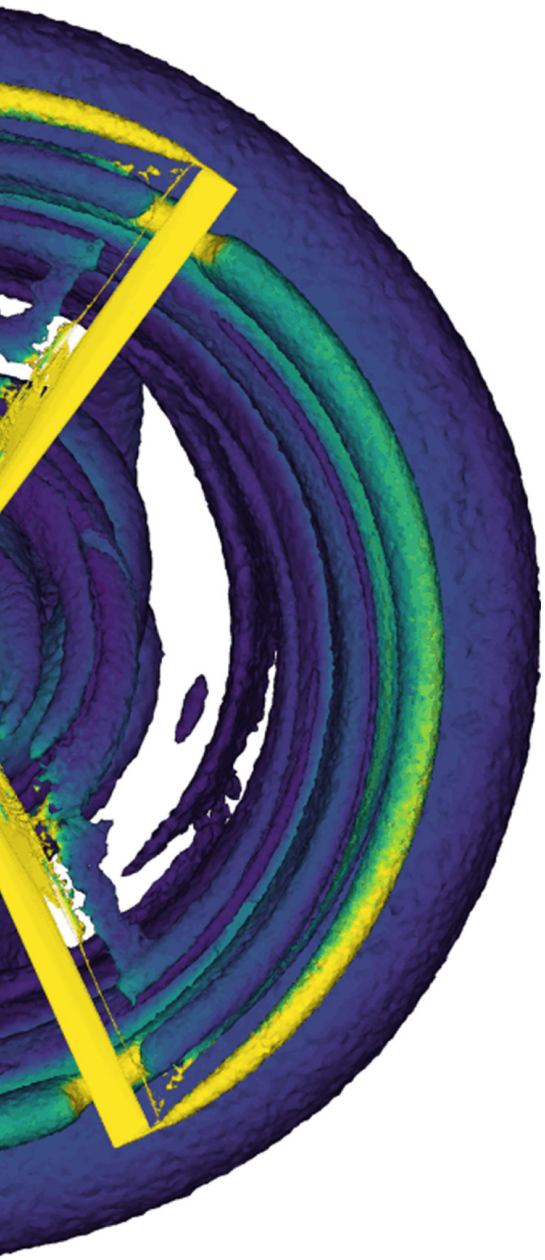
All this leads to significant reductions in CFD simulation time, engineering frustration, and analysis resources. This means reducing product risk and accelerating the time to market, all at a lower cost.

> "Demonstrates remarkably high efficiency and is around 1 to 2 orders faster then the usual high fidelity solvers on the market"

Wei Liao
Lead aerodynamicist at Bihrle.

Advantages of Flow360 and how it solves the above bottlenecks

Flexcompute's CFD solution is an improvement on traditional CFD methods for a multitude of reasons:



1

It provides aerodynamicists with an easy to use cloud based platform geared for CFD. This means that they no longer need to worry about buying, installing, maintaining, and upgrading any HPC hardware or fighting with cloud based HPC solutions; Flexcompute engineers have done it all. They handle all the complexities of running on cloud HPC resources and pass on all the advantages.

2

Users pay for CFD runs using a token system of "FlexUnits". Companies can run as few or as many CFD cases as needed without overpaying in periods of lulls or being constrained during periods of high use. This allows for greater flexibility when CFD needs vary. Flow360 is there when needed and doesn't cost anything when not actively used.

"Flow360 gives access to state-of-the-art results, without the overhead of maintaining a large dedicated CFD group"

Chris Courtin
Lead Engineer
at Electra.aero

3

The speedup that comes from Flow360 is twofold:

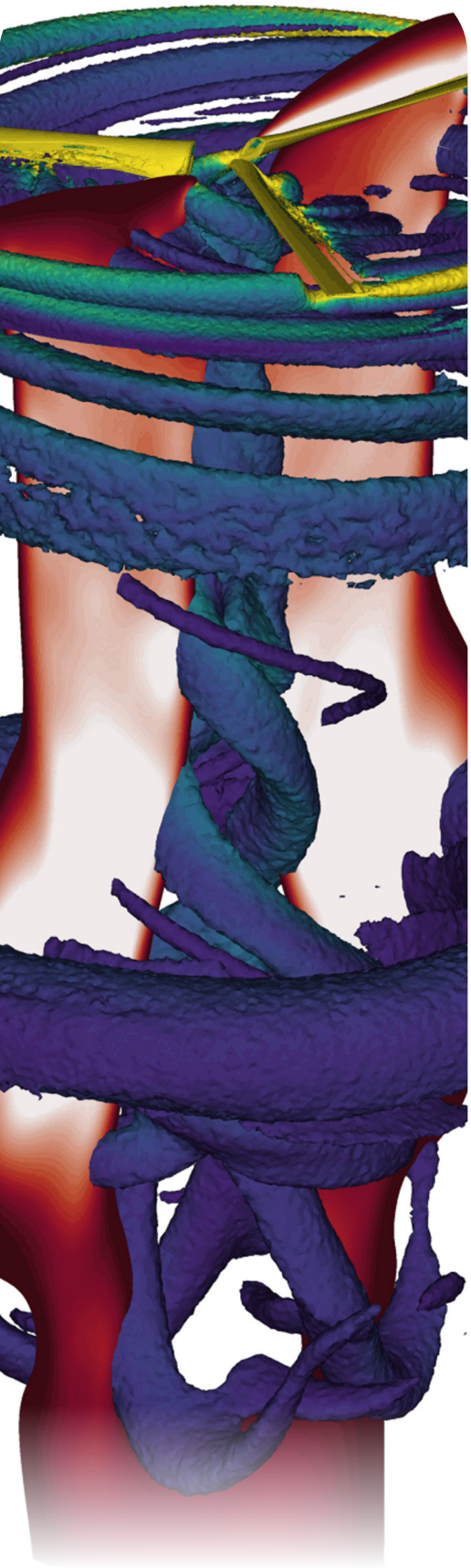
- By making a solver that is 100s of times faster than other commonly available CFD solutions, the Flexcompute infrastructure can give back results in minutes instead of many hours or even days. It can handle any size simulation.
- Accessing cloud based HPC hardware allows for the scaling of resources to match any team's demands. This means that they don't have to wait weeks for large matrices of runs. Flexcompute automatically spools up HPC instances and runs all of the desired cases in parallel.

4

When it comes down to it, the largest cost in running HPC hardware is the electricity to power it and keep it cool. Because Flow360 is so much more efficient it uses much less electricity. These savings get passed on to the end user.

5

By working closely with the MIT team building the ESP software, the Flexcompute team has designed a fully automated process from parametric CAD generation, to meshing, to CFD solution, and finally to postprocessing. This means that users can now modify a geometry in seconds and then let computers do all the painstaking work of meshing and running the CFD solution. This process ensures a greater consistency of meshes across designs and helps accelerate the turnaround time from human days to computer hours.



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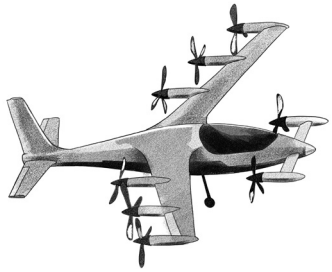
Flow360 provides an intuitive web-based user interface as well as a powerful Python-based API. The Python API allows Flow360 to be quickly integrated into any existing tool chain.

7

With an extensive list of options, aerodynamicists can get the CFD solutions they require. Flow360 provides:

- A fully compressible Navier-Stokes solver
- Steady and unsteady viscous flows with a wide range of the most common turbulence models
- Coupled stationary and rotating domains
- Nested rotating domains
- Detached Eddy Simulation
- Laminar-Turbulent Transition model
- Blade Element Theory model
- Actuator Disk model
- Porous Media model
- User Defined Dynamics

On the off chance that a required feature is not available, Flexcompute can implement it in record time.



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Not only is Flow360's speed and flexibility unprecedented but its accuracy is also second to none. Flexcompute engineers constantly strive to validate CFD solutions against most of the common industry benchmarks.

"

Flexcompute has been instrumental in helping us develop the workflows that enable these quick iterations....They are helping us create a system where we can efficiently explore the design space at a fraction of the engineering cost.

"

9

Flexcompute has some of the best CFD experts on the market, including 16 PhDs in CFD related fields. More than a century of aerospace CFD experience is ready to help companies solve their aerospace design problems. Because of the smaller team size, if support engineers are not able to quickly answer questions, they can, and do, go directly to the people who truly know the code to find the best answers.

10

Any team's data is precious and sending it to the cloud may be concerning. To ensure that Flexcompute adheres to the highest data security standards, access control is strictly maintained on systems and team members are regularly educated on data security best practices.

Arthur Dubois
Director
Aero-structures

Practical examples of benefits

In order to demonstrate the value and impact of Flow360 on the aerospace design process, below are several case comparisons provided by customers. They previously used a NASA high accuracy CFD solver on the AWS cloud and compared their previous results to those achieved with Flow360.

Aircraft A.
The mesh has 22.3 million nodes, Mach number is 0.3 with an angle-of-attack of 2°

	NASA Solver	Flow360
Solver Time	511 minutes	4.1 minutes
Hardware	256 Core CPU	Advanced Chips
Computing	2184 CPU-hour	10 FlexUnits
Unit Cost	$0.04/CPU-hour	$3.5/FlexUnit
Total Cost (USD)	$87	$35

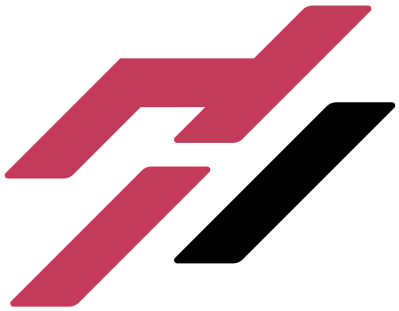
Aircraft B.
The mesh has 18.4 million nodes, Mach number is 0.85 with an angle- of- attack of 3.3°

	NASA Solver	Flow360
Solver Time	1400 minutes	7 minutes
Hardware	256 Core CPU	Advanced Chips
Computing	5973 CPU-hour	25 FlexUnits
Unit Cost	$0.04/CPU-hour	$3.5/FlexUnit
Total Cost (USD)	$239	$87.5

Not only were they excited by the much faster run times and lower cost, but the accuracy was aligned with prior validations. They are now regular users of Flow360.

Let’s get started

Interested in taking your CFD solutions to the next level, improving your CFD engineer’s efficiency, and getting better CFD results faster and cheaper? Simply curious to see what Flexcompute could do for your company? Please visit www.flexcompute.com or contact us. Follow us on LinkedIn for useful updates, publications, and other resources.



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