

Air Force Conducts Large-Scale Aerodynamic Simulation with Amazon EC2

To speed the development of more fuel efficient and durable jet engines, the U.S. Air Force Research Laboratory and AeroDynamic Solutions (ADS) partnered with Amazon Web Services to devise an effective design simulation solution. With Amazon Elastic Compute Cloud (Amazon EC2), ADS proved that large-scale aerodynamic simulations can be dialed up on-demand and performed affordably and within the time constraints of commercial design.

Background

For the world's leading manufacturers of jet engines, product development remains an extremely costly and time-consuming task. Modern designs have pushed traditional analysis methods to the limit, demanding the use of advanced simulation techniques to better tackle performance and durability issues before committing to hardware. To address these concerns, the Turbine Branch of the United States Air Force Research Laboratory (AFRL) and ADS joined forces to advance one such simulation technique—large-scale time accurate simulation—for the U.S. gas turbine industry. The Turbine Branch is responsible for advancing the technical capability of turbo propulsion systems, and ADS provides Computational Fluid Dynamics (CFD) software and analysis services to the world's manufacturers of jet engines, industrial gas turbines, and compressors.

Time accurate simulation enables designers to understand how time-varying aerodynamic loads can lead to performance loss and structural fatigue. Though this analytical method has long been available, it has largely remained out of reach for commercial design due to its high computational cost and long turnaround time.

To carry out large-scale time accurate simulation, hundreds of clustered processors may often be required, necessitating enormous upfront hardware, software and support personnel costs. As a result, this type of simulation has largely remained out of reach to all but the largest of gas turbine manufacturers. Another problem is that time accurate simulation can take weeks to run, rendering it impractical for commercial design cycles.

Working under an SBIR Phase II award from the U.S. Air Force, ADS enhanced its large-scale time accurate analysis capabilities to tackle these issues. As part of this effort, ADS turned to Amazon Web Services (AWS). Using Amazon EC2, AeroDynamic Solutions gained the capabilities of a large commercial cluster on demand and at a fraction of the cost.

Approach

To demonstrate the capabilities of the ADS/AWS solution, the U.S. Air Force-designed Notre Dame HiLT 1.5 stage turbine was analyzed for unsteady effects. Consisting of 165 passages with 60/70/35 airfoil counts per row, the HiLT turbine is a highly

loaded, transonic, low pressure turbine representative of today's modern designs. For the analysis, one-fifth (1/5) of the full wheel (12/14/7) was simulated for a complete revolution. After generating the mesh and completing initial 3-D multi-stage analysis, the EC2-enabled ADS solution performed as follows:

- The mesh (10.6 million elements) was partitioned into 40 blocks for parallel execution on the ADS solver Code Leo.
- 40 processors were dynamically provisioned on Amazon EC2 utilizing five cc1 cluster compute instances.
- Code Leo was invoked across the 40-processor cluster, simulating 10,500 time steps with 20 inner iterations per time step.
- Results were gathered and delivered to local servers for post-processing and analysis.
- EC2 instances were deleted upon completion.

Security issues were addressed as well: SAS 70 Type II certification and VPN-level access were required; uploaded and downloaded data was encrypted; dedicated cc1 instances were provisioned to ensure that data mingling did not occur; and data was purged upon completion of the case.

Results

The results of this case were impressive. Using Amazon EC2 the large-scale, time accurate simulation was turned around in just 72 hours with computing infrastructure costs well below \$1,000. Additionally, time accurate analysis revealed critical insights that were not detected using traditional analysis techniques—most notably a 2% drop in efficiency relative to conventional 3-D multi-stage steady predictions.

Dr. John Clark, Turbine Branch, Turbine Engine Division, Propulsion Directorate of the Air Force Research Laboratory, explains the importance of this case: "Advancing turbine durability and performance remains critical for the U.S. gas turbine industry. The combination of high fidelity time accurate analysis from ADS and on-demand CFD analysis resources from Amazon makes it possible for turbine manufacturers to tackle these issues during design—quickly and without the need for large hardware investment."

George Fan, CEO of AeroDynamic Solutions, is equally thrilled with the results: "Traditional 3D steady analysis techniques are no longer sufficient to support the design of today's advanced jet engines. To improve durability and performance, advanced analysis capabilities such as time accurate simulation must be made to work within the accuracy, time, and cost constraints of a commercial design cycle. We're delighted to be working closely with the Air Force and AWS to make this a reality for designers large and small."

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Air Force Research Laboratory