NIMBIX
CASE STUDY

Firefly Aerospace partners with Nimbix to design high-quality, cost-efficient engine components for its space launch vehicles

"At Firefly, what we work on is quite literally rocket science. It takes an enormous amount of simulation and modeling—not to mention computing resources—to design components that withstand the tremendous heat and pressure during a space launch. With Nimbix, we have the flexibility to run what and when we want, regardless of the size of the job, without waiting in line for resources. That means we quickly get the answers we need to design components that are both optimized and manufacturable at a reasonable cost."

David McKinnon
Propulsion Analysis SME,
Firefly Aerospace

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INTRODUCTION

Founded in 2017 by Dr. Tom Markusic, Dr. Max Polyakov and Mark Watt, Firefly Aerospace is a leading developer of small launch vehicles. Its motto is simple: "making space for everyone." Big communications satellites are often the size of a city bus, but an increasing number of smaller satellites are targeted for lower orbits. The owners of these satellites can't afford to wait or pay the full price for larger launch vehicles. Firefly—best known for the Firefly Alpha, a small satellite launcher that can deploy 1000 kg to Low Earth Orbit—solves that problem.

Designing quality components for the Alpha and other Firefly vehicles is no simple feat, however. Components for rockets require extremely precise modeling with no room for error. The company must have the highest confidence in its designs, as the components are expensive to manufacture and are most often tested only in actual flights. Because the simulations are so complex and require such intense computation resources, Firefly needed the resources, flexibility, and reliability of an HPC partner like Nimbix.

CHALLENGES

Due to the sheer volume of data, bandwidth, and number of cores Firefly's simulations required, its previous HPC provider's infrastructure and interfaces made it difficult (if not impossible) for the team to rapidly iterate, debug, and refine its designs. Such was the case the analysis of the Lightning engine's nozzle extension, a part of the rocket engine that is used only once the engine goes to space.

Temperatures inside a rocket engine can exceed 6,000°F, so most of them are actively cooled with the rocket fuel. The nozzle extension is quite large and is cooled by heat radiation, but it is also "insulated" from the main engine's hot gas by film cooling—a flow of the relatively cooler (1,000°F) turbine exhaust gas around the nozzle extension. Simulating how these two streams of gas mix as they pass each other at supersonic speeds is very complex.

Running a large rocket engine in a vacuum chamber is difficult and expensive, so components like the nozzle extension are only tested in flight—meaning the success or failure of a launch could come down to the precision of the design. To ensure the optimal design, Firefly needed computing resources that were readily available, highly scalable, and easy-to-use, allowing them to spin up new jobs in minimal time regardless of their size—while only paying for the resources they actually use.

"A single simulation might involve solving six equations with six unknowns and a hundred million data elements, and solving 600 million equations per iteration can easily require 10,000 core hours," said McKinnon. "We can't wait around in the queue for compute resources to become available. We needed an HPC provider able to handle the volume, frequency, and sheer computing power to explore and find creative solutions to very real problems."

TECHNOLOGY USED

McKinnon and his colleagues use computational fluid dynamics (CFD) simulations to model three forms of heat transfer that affect the nozzle extension: convection, radiation, and conduction. They utilize Ansys CFD software—primarily Ansys CFX and Ansys Fluent—as well as Ansys Mechanical for structural analysis. They also run CFD simulation and design programs developed by NASA, including NASTRAN (finite element analysis), NASA CFD codes to simulate fluid flow, as well as Cart3D and FUN3D.

Running on the on-demand resources of the Nimbix Cloud HPC infrastructure, these tools allow Firefly to accurately model how the heat and forces will affect the nozzle extension during actual rocket flights. Each model uses between 20 and 110 million elements in CFX to conjugate heat transfer efficiency. The models simulate the complex interactions of the hot engine gas and insulating turbine exhaust gas as they flow past each other, as well as the heat conduction through the solids, to determine how well the nozzle extension will be cooled. A typical simulation using these models can easily require 1,000 cores for 12 or more hours.

ENGINEERING SOLUTION

According to McKinnon, the Nimbix HPC cloud infrastructure provides the flexibility to submit any size simulation job at any time and be assured minimal wait time to begin execution. Readily available resources mean they can get the answers they need to make optimal design decisions faster. For example, an analyst was able to run 15 iterations in only one week to design a baffle that optimally distributes the flow of film cooling gas onto the nozzle extension. The analyst's design could also be manufactured at a reasonable cost.

Nimbix allowed the team to more efficiently tackle problems like these by providing:

- The cores and speed necessary to shorten design iterations from days to mere hours
- The on-demand availability of HPC infrastructure and bandwidth to run multiple simulations in parallel, further shortening overall design time
- The ability to quickly analyze huge datasets, evaluate new engineering design concepts and optimize the design of critical components for Firefly's rocket launch vehicles

BENEFITS

The solution designed for the plenum and nozzle extension saves hundreds of thousands of dollars per engine compared to other approaches used in the industry.

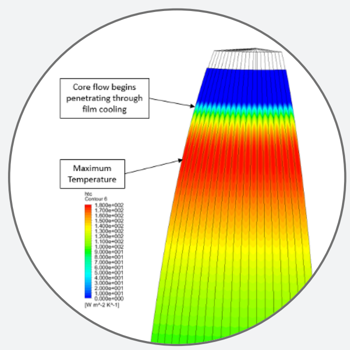
With Nimbix, Firefly was able to make faster analyses and design decisions, solving the nozzle extension cooling problem far more rapidly than with its previous HPC provider. Nimbix also enabled the team to identify less expensive methods of building the film cooling plenum and nozzle extension, while still ensuring that they meet strict design requirements. These are critical in an industry like aerospace engineering, where components like these cannot be cost-effectively tested except during an actual launch.

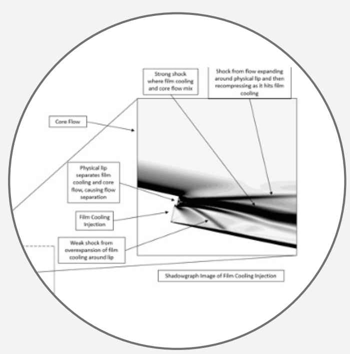
“Iteratively building and testing physical parts in a vacuum chamber that replicates actual launch conditions is prohibitively expensive,” said McKinnon. “The speed and accuracy of simulations we’re able to run with Nimbix help us build our clients a more reliable yet less expensive rocket that will perform as expected under actual conditions.”

COMPANY DESCRIPTION

Firefly is developing a family of launch and in-space vehicles and services that provide industry-leading affordability, convenience, and reliability. Firefly’s launch vehicles utilize common technologies, manufacturing infrastructure, and launch capabilities, providing Low Earth Orbit (LEO) launch solutions for up to ten metric tons of payload at the lowest cost/kg in the small-lift class. Combined with Firefly’s in-space vehicles, such as the Orbital Transfer Vehicle and Genesis Lander, Firefly provides the space industry with a one-stop shop for missions to the surface of the Moon or beyond.

Headquartered in Cedar Park TX, Firefly has additional presences in Washington, D.C., and Dnipro, Ukraine. Firefly is financed by Noosphere Ventures of Menlo Park, CA.





Among other complex applications, Firefly uses Nimbix to simulate how its rockets’ turbine exhaust gas can optimally insulate the critical nozzle extension from the super-heated gas produced by the main engine.