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Aerospace and defense

Martin UAV

Drone maker uses Simcenter STAR-CCM+ and HEEDS to deliver the world's first true ducted fan VTOL UAV

Product

Simcenter

Business challenges

Design an innovative VTOL UAV

Quickly analyze thousands of designs

Identify optimum design for best hover and cruise performance

Improve payload, fuel capacity and flight time

Keys to success

Design optimization process with Simcenter STAR-CCM+ and HEEDS

Use Simcenter STAR-CCM+ to conduct full CFD, high-fidelity analysis of duct performance

Use HEEDS to perform CFD analysis of hundreds of duct designs

Results

Built first true ducted fan VTOL UAV

Delivered innovative, optimized duct design without prototypes

Increased hover thrust by 5.8 percent yet decreased cruise power by 3.8 percent

Increased flying time to more than eight hours with a payload of more than eight pounds and a range of 350 miles

Rise of the V-BAT

Somewhere in a field in Plano, Texas the future of military surveillance and reconnaissance sits inconspicuously in the back of a pickup truck. It's an odd place to spot the next generation of tactical unmanned aerial systems (UAS) for the United States Army, Marine Corps and Navy. Then again, this is a unique drone. This is the V-BAT, the world's first true vertical takeoff and landing (VTOL) tailsitter (meaning it takes off and lands on its tail) unmanned aerial vehicle (UAV).

At first glance, it looks like an ingenious scientist just attached wings and blades to a life-sized lipstick. But the technology behind it is mighty impressive. The long-endurance V-BAT takes off vertically from small, confined areas and seamlessly switches to horizontal flight. This is quite a feat considering trying to achieve a clean transition from vertical to horizontal flight has previously derailed many ambitious vehicle projects; or they have ended up being multi-copter hybrids or sounding like a flying lawnmower, neither of which fit military reconnaissance missions.

With the V-BAT, Plano-based Martin UAV has not only solved one of the hardest problems in transition flight, but delivered a UAS fit for the future – a true VTOL drone capable of taking off without a runway and flying for more than eight hours with a payload of more than eight pounds, with a top speed of just over 100 miles per hour (MPH) and a range of 350 miles.

The UAV of the future is here (and it's in a box)

The V-BAT is currently in a race to replace the venerable Shadow, the Army's aptly named workhorse drone since 2004. As part of the U.S. Army's modernization efforts, the future vertical lift (FVL) team is seeking a replacement for the long-standing Shadow. What the Army is looking for is a runway-independent UAS with improved range and greater endurance, which is easier to use and move around the battlefield, and systems that reduce acoustic signatures to avoid enemy detection.

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Zach Hazen
Aerodynamicist
Martin UAV

Figure 1. V-BAT during launch.

Martin UAV's V-BAT, which comes in a transportable box, checks all these boxes, with the bonus of being quite safe because it has no exposed rotor blades.

The V-BAT can take off vertically from anywhere and can land repeatedly, precisely and autonomously in an area eight feet-by-eight feet from hovering several hundred feet above. It can even land in the back of a moving pickup truck.

The Army wants improved range, and with the ability to stay aloft for more than eight hours in horizontal flight, the V-BAT takes care of that.

It is also easy to maneuver around a battlefield. It fits inside a transportable case in the back of a pickup truck, providing equipment independence.

Users also cite the reduced acoustic signature in cruise flight due to the ducted propellers that minimize noise.

Any way you look at it, the V-BAT is easily meeting the expectations of UAS users. Austin Howard, V-BAT's chief engineer, says, "Where others are stuck adapting existing platforms, the V-BAT is designed from scratch to be the safest, simplest and most tactical UAV in the Group 2/3 space."

Simulation in the V-BAT design

From the start, Martin UAV wanted to build a true VTOL system and not a hybrid. Hybrids spend a lot of electric power getting airborne – power that's lost when it comes to payload-carrying capacity. A true VTOL system design has complex challenges, particularly designing for a high thrust for hover

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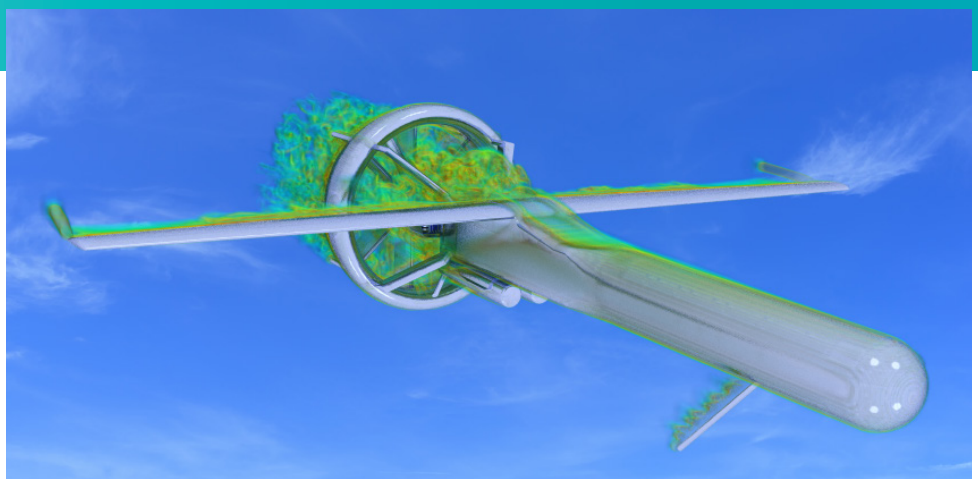

Figure 2: Simulation of the V-BAT aerodynamics with Simcenter STAR-CCM+.

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>
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> Chief Engineer
> Martin UAV

while also reducing drag for cruise. In simple terms, you are designing a helicopter and forward-flying aircraft in the same product, except the V-BAT cannot look like either.

Martin UAV's years of industry experience meant the first design was built from lower order tools, handbook methods and experience. The idea was simple – build, test and fly. And it worked, largely in part due to the genius of the design. In fact, it worked so well the design was operation-test ready for customers.

But Martin UAV had loftier goals to achieve the best design possible and turned to Siemens Digital Industry Software's Simcenter™ software simulation and test suite of solutions.

Zach Hazen, aerodynamicist for the V-BAT, swears by digital simulation: "Our customers want more payload, more fuel carrying capacity and longer flight time. High-fidelity simulation is a way to stay ahead of their demands."

Duct, duct, choose

What makes the V-BAT work so well is the unique ducted-fan tailsitter configuration – the heart and soul of the drone. Ducted fans include a propeller (fan) and a duct, both connected to the fuselage by struts. Behind the rotating propeller lies a stator inside the duct and control surfaces outside that act as an aileron, a rudder and elevators.

Ducted fans are a boon for UAV applications. They can operate safely in highly confined areas and the environmental and noise footprint is minimal. The enclosed propeller blades act as a shield for noise and blade tip performance losses. Takeoff and hover performance are more efficient with a ducted fan configuration compared to open rotos. In horizontal flight, the ducted fan provides stability as a horizontal tail.

With its many benefits critical to the success of the V-BAT, it is no wonder that getting the V-BAT design right meant getting the duct design right. For Martin UAV, multiple objectives of the duct complicated matters. To achieve the best possible efficiency in vertical hover flight, the shrouded propellers needed a thick cross-section to generate enough thrust. On the other hand, reducing the drag in horizontal cruise flight needed a thin propeller cross-section to minimize the area of propeller facing air resistance.

How do you design something to be thin and thick at the same time? The answer: design optimization with Simcenter. In simple terms, Hazen needed to analyze hundreds of duct designs to choose the best compromise, something beyond the wildest dreams for any testing.

"When looking at designing a new duct, we looked at quite a few by hand by changing important duct parameters. This was very man-in-the-loop and we analyzed only a handful designs and were less sure of our optimum design," notes Hazen.

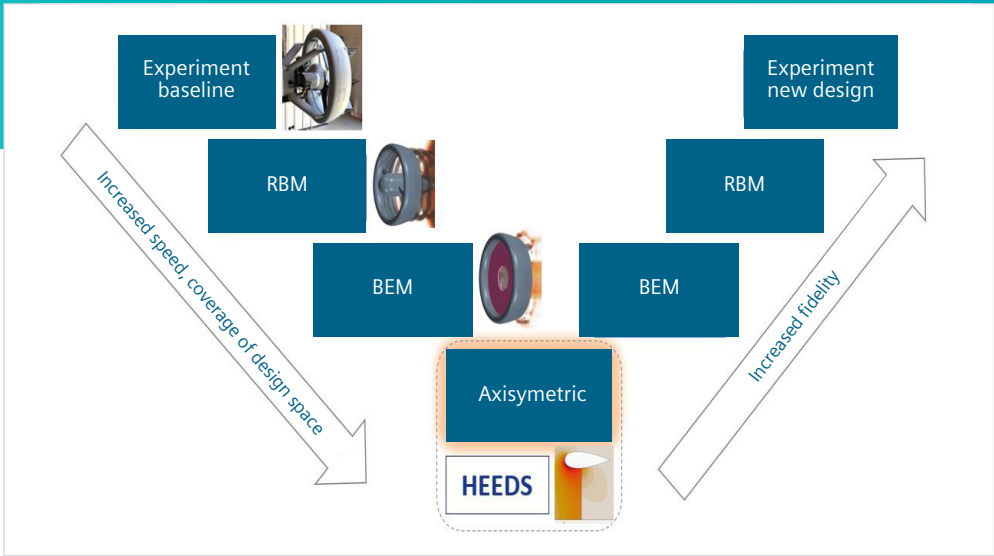

Figure 3: The design optimization process for the V-BAT duct.

Finding the optimum duct design

Martin UAV turned to Simcenter to perform the duct optimization. With Siemens Digital Industries Software's Simcenter STAR-CCM+™ software, the firm conducted a full computational fluid dynamics (CFD) analysis of the duct performance in hover and cruise conditions, including a hover figure of merit and fixed-wing propulsive efficiency.

Hazen remembers the reason for choosing Simcenter STAR-CCM+: "We invited a few companies to validate our product at a known design point and landed with Simcenter STAR-CCM+ because it won the competition. We weren't just looking at the quantitative answers, but also at how their engineers listened and gave answers. We were extremely impressed with the Simcenter support engineers."

In particular, the blade element method (BEM) capability let Martin UAV get a good approximation at a low computational cost by approximating rotor performance characteristics. For more promising designs, Martin UAV used a higher fidelity analysis with a rigid body motion (RBM) model to enable simulation of full rotating propellers, providing a detailed, more accurate performance prediction.

"I'm buying software with an array of tools to give either fast answers covering a lot of the design space with assumptions or perform high-fidelity simulations for detailed answers," says Hazen.

Siemens Digital Industry Software's HEEDS™ software, an automated design exploration tool, was then used to run a full design optimization by changing the duct design to hundreds of configurations intelligently and running the CFD analysis on each. Martin UAV suddenly had the ability to design, analyze and automatically find the optimum duct design that satisfied their multiple objectives. "With HEEDS, we could iterate through

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Solutions/Services

Simcenter STAR-CCM+
siemens.com/simcenter

HEEDS
siemens.com/simcenter

Customer's primary business

Martin UAV's mission is to build the world's most advanced unmanned systems. The firm's technology team specializes in building tactical systems from the ground up and addressing the vast capability gaps left by legacy technologies and current government programs of record around the world.
www.martinuav.com

Customer location

Plano, Texas
United States

hundreds of designs for several runs of hover and cruise. I was pleasantly surprised at the kind of answers and insights we got," Hazen notes.

With digital duct optimization, Martin UAV found designs that increased the hover thrust by 5.8 percent yet decreased the cruise power by 3.8 percent, which meant there was more capacity for payload and fuel, and longer flight times were possible. The new design makes it all possible.

For a small company with lofty goals, using digital design optimization was a no-brainer and the only way to analyze thousands of duct designs before a single prototype was built.

Designing the future with digital twins

Today, designing a new product without using digital simulation and digital twins is akin to walking onto a battlefield without armor or a weapon. Every industry is being disrupted by new business models and technology and engineering a revolutionary product is no different. For engineers and designers like Hazen, the pressure to get innovative products right the first time and provide fast results for customers means deploying digital simulation early and often in the design phase.

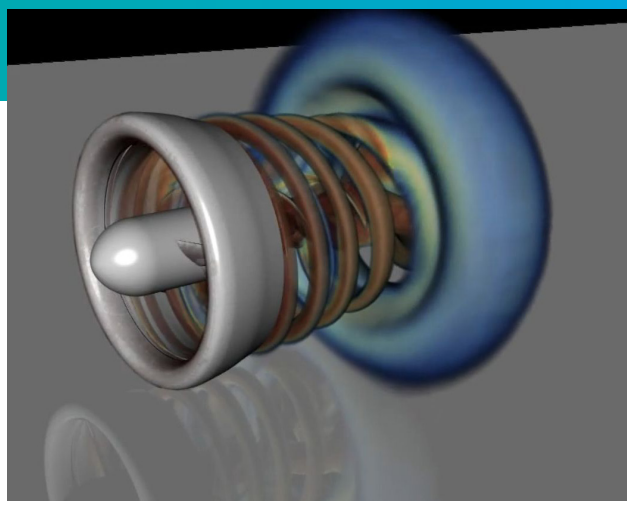

Figure 4: Simcenter STAR-CCM+ simulation showing vortices from one of the optimum duct designs.

Martin UAV and Hazen bought into digital simulation early. The result: A true VTOL UAV that may end up being a valuable reconnaissance asset for the Army. The V-BAT is already one of the finalists to replace the Shadow. Unsurprisingly, the V-BAT doesn't just have the U.S. Army and other military branches buzzing. Additional interest has been expressed for organizations conducting tactical reconnaissance, aerial mapping, shipboard operations, anti-piracy operations, farming and law enforcement – the applications for a versatile VTOL drone with a reasonable price tag are endless.

In the animal kingdom, bats are the only true flying mammals. Martin UAV's V-BAT is now staking the same claim in the drone kingdom.

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