WOLF Advanced Technology

THE X-59: THE FUTURE OF FLIGHT

– WHITEPAPER

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ADVANCED TECHNOLOGY

INTRODUCTION

Since the Wright Brothers first took flight in 1903, aviation technology has progressed at an unprecedented pace. Advancing through the decades, aviation began to encompass aerospace and the ultimate frontier. By the 1970s, the industry had reached a new frontier, one that encompassed both air travel on Earth and beyond—supersonic travel. However, merging the technology used in space travel to that with Earth travel proved to be complicated. Whereas space travel required an extreme degree of speed, flight on Earth did not allow for the same velocity. This disparity allowed for the technology and trajectory of space travel to flourish, but restricted Earthly flights from reaching the same futuristic capabilities. The primary limitation for Earth flights was the sonic boom. More than a loud nuisance, these shockwaves posed safety concerns for humans and animals and generated widespread noise pollution. In response, the Federal Aviation Administration (FAA) banned supersonic flight over land in 1973, a regulatory milestone that, while necessary at the time, stalled commercial development in high-speed aviation. Hence, those in the industry were faced with an issue: how could they continue to advance flight technology overland while also abiding the bureaucratic limitations instilled onto them from the FAA. Until they could answer this question, the trajectory of air travel was stalled, awaiting the technology necessary to take the industry out of its stagnant 1970s designs, and into the future.

NASA's Quiet Supersonic Transport (QueSST) mission aims to rewrite that narrative and catapult air travel forward. At the center of this effort is the X-59, a purpose-built experimental aircraft engineered to drastically reduce the acoustic footprint of supersonic flight. By elongating the fuselage and optimizing its aerodynamics—most notably through an exceptionally long, narrow nose—the X-59 mitigates shockwave coalescence, producing a subdued "sonic thump" rather than a traditional boom. The noise is equated to being similar to the sound of a car door slamming shut, far less of a nuisance and danger to human and animal life than an actual sonic boom would pose. This design enables the possibility of overland supersonic travel that is both regulatorily viable and publicly acceptable. However, the innovative nose geometry introduces a new challenge: it eliminates the forward visibility typically afforded by a cockpit canopy.

To solve this, NASA developed the eXternal Vision System (XVS), a sophisticated sensor and display solution that virtually reconstructs the pilot's forward view using a combination of onboard cameras, real-time image processing, and custom display interfaces. This marks a fundamental shift in how situational awareness is achieved in next-generation aircrafts.

This whitepaper explores the X-59 program and the advanced embedded technologies enabling its success. It highlights WOLF's role in delivering rugged, high-performance video processing modules integral to the XVS, and outlines how GPU-accelerated hardware is helping redefine what's possible in modern aerospace design. Together, NASA and WOLF are enabling a leap forward in aviation—quiet, fast, and ready for the 21st century.

THE EXTERNAL VISION SYSTEM (XVS)

A defining feature of the X-59 aircraft is the absence of a forward-facing cockpit windshield. Unlike traditional supersonic aircrafts, where the pilot's visibility is supported by a physical line of sight through the canopy, the X-59 replaces this conventional structure with a long, aerodynamically optimized nose. Such a nose prevents the installation of a forward-facing window, leaving the pilot without a direct line of sight. While this design is essential to shaping the aircraft's sonic signature and achieving the goal of low-boom supersonic flight, it creates a unique challenge: how to ensure pilot situational awareness and safety without any direct forward visibility.

Image 1. A construction of what an operational X-59 will look like once it takes flight.

NASA proposes the XVS as the ultimate solution to this newfound problem. The XVS integrates multiple ultra-high-definition (UHD) camera feeds mounted on the aircraft's forward fuselage and top fin. These cameras provide continuous, high-resolution views of the airspace ahead and below the aircraft, which are then processed and displayed in real time on a cockpit monitor located directly in front of the pilot.

From a systems engineering standpoint, the XVS must meet an extensive set of performance requirements. First, the system must provide an image that closely mimics the depth, clarity, and responsiveness of human vision through glass. This requires ultra-low latency between video capture and display, typically within tens of milliseconds, to ensure that pilot inputs and reactions are accurately timed with real-world events. Lag or dropped frames in such a system could severely compromise safety, particularly during takeoff, landing, and low-altitude maneuvers. It is vital that the XVS mimic real human perceptions in order to replace the actual value of physical sight.

Second, the vision system must perform reliably across a wide range of environmental conditions. The X-59 is expected to cruise at altitudes exceeding 50,000 feet, where ambient temperatures can fall below –50°C and atmospheric pressure is significantly reduced.

During descent and approach, the system must continue operating seamlessly through turbulent and humid conditions, direct sunlight, and sudden shifts in contrast or brightness. The cameras and display system must also handle rapid changes in lighting conditions, such as flying through clouds or transitioning from day to dusk, without loss of visibility or image distortion.

The physical and electrical characteristics of the XVS hardware add another layer of complexity. All components must be ruggedized for aerospace deployment, meaning they must resist vibration, shock, electromagnetic interference (EMI), and long-term fatigue. Redundancy is also critical; the system cannot afford a single point of failure, so it must include backup camera paths, failover protocols, and
health-monitoring diagnostics.

To meet these rigorous requirements, NASA and Lockheed Martin collaborated with a select group of hardware partners capable of delivering flight-qualified, high-reliability electronics. Among these partners, Wolf Advanced Technology was chosen to provide the video acquisition subsystems that form the backbone of the XVS. WOLF's expertise in rugged embedded computing, along with its specialization in high-resolution video handling and GPU-driven processing, made it uniquely qualified to support a mission of this complexity.

Image 2. Imagining of the interior of the plane and the piolet's point of view.

WOLF's solution for the XVS is built on its proven XMC module architecture, incorporating the second-generation Frame Grabber Extreme (FGX2) video processing engine alongside GPU-based display units. In the X-59 application, the FGX2 captures digital high-speed inputs such as CoaXPress, as well as legacy analog inputs. Additional functions—including frame synchronization, resolution scaling, image enhancement, and real-time rendering—are performed by the GPU unit (possibly the WOLF-3170, with software support provided externally).

The resulting processed video stream is then delivered to the cockpit display as a clean, stabilized visual interface, enabling the pilot to interact with the virtual view as intuitively as a physical one.

In practice, the XVS integrates with the aircraft's avionics to deliver not just raw imagery but also overlays of flight-critical data. This includes synthetic flight paths, instrument readouts, and telemetry-based horizon indicators, similar to those used in head-up displays (HUDs). This fusion of sensory and navigational data creates a more comprehensive pilot experience, one that enhances awareness rather than simply replacing a glass canopy.

The implementation of the XVS represents a significant step forward in aerospace cockpit design. It opens the door to windowless aircraft configurations that are lighter, more aerodynamically efficient, and potentially more secure. It also serves as a technological testbed for future applications, including next-generation commercial aircraft, unmanned aerial vehicles (UAVs), and spacecraft where direct pilot visibility is inherently limited or impossible.

In short, the XVS is not merely a workaround for a design challenge. Rather, it is a forward-looking innovation that redefines the relationship between the pilot and the environment. By supplying the critical hardware that powers this system, Wolf Advanced Technology is helping usher in a new era of vision systems for aviation. Their hardware ensures that the X-59 pilot is never flying blind, even in the absence of a traditional glass window. This contribution is not only essential to the success of the QueSST mission but also has broader implications for the future of aerospace design and operations. Such technology will allow people to fly in environments where physical sight was necessary, and a lack of it was dangerous and restrictive. Now, pilots can fly anywhere, showing how the X-59 is an innovation and high-tech plane.

AERODYNAMIC FEATURES & ACOUSTIC PHYSICS

Central to the X-59's groundbreaking ability to reduce sonic booms is its highly specialized aerodynamic design, which manipulates the physics of supersonic flight. The aircraft's distinctive long, narrow nose—measuring nearly 38 feet—serves a critical function in reshaping the way shockwaves travel through the air. Traditional supersonic aircrafts produce a sudden, disruptive pressure change when breaking the sound barrier, resulting in a loud and sometimes damaging sonic boom heard on the ground. The X-59, however, is engineered to control and distribute these pressure waves differently.

By elongating the fuselage and refining the nose to a sharp point, the X-59 gradually displaces air as it travels at supersonic speeds. This extended shape prevents the typical shockwave coalescence that causes a sonic boom. Instead of merging into one intense pressure wave, the shockwaves are staggered along the length of the aircraft, minimizing their intensity and spatial compression. This restructuring results in a much quieter sonic footprint—what NASA refers to as a "sonic thump" rather than a "boom."

Further enhancing its acoustic performance is the aircraft's engine placement. Rather than mounting the engine beneath the fuselage or on the wingtips, locations that could amplify ground-level noise, the X-59's single engine is positioned on top of the fuselage. This positioning ensures that much of the engine noise is directed upward, away from populated areas. The aircraft also lacks a forward-facing cockpit window; instead, it relies on the eXternal Vision System (XVS), which uses cameras and display screens. This design choice allows for an uninterrupted aerodynamic surface, improving both drag reduction and shockwave shaping.

In combination, these design features allow the X-59 to travel at Mach 1.4 (approximately 925 mph at cruising altitude) while producing a ground-level sound signature of only about 75 perceived decibels—roughly equivalent to a car door slamming from a distance. These innovations not only serve NASA's Quiet Supersonic Technology (QueSST) mission but also establish a framework for the development of commercial supersonic aircraft that could one day fly over land without disturbing people on the ground.

WOLF ADVANCED TECHNOLOGY'S ROLE

At the core of NASA's X-59 eXternal Vision System (XVS) is a suite of high-performance video processing and display hardware supplied by Wolf Advanced Technology. WOLF's involvement in the QueSST program is centered on its ruggedized XMC modules, engineered for the kind of high-throughput, low-latency, and mission-critical performance demanded by next-generation aerospace applications. Specifically, WOLF's contributions include the XMC-FGX2-SDI-4IO (WOLF-3180), as well as the GPU-powered XMC-E9171-VO (WOLF-3196) display module. Together, these products comprise the image processing backbone of the XVS, enabling the aircraft to replace its missing windshield with a synthetic, real-time visual field.

The XMC-FGX2 family of frame grabber modules lies at the front end of the video acquisition pipeline. These modules are designed to ingest multiple synchronized video feeds. It can hold up to four channels in the case of the WOLF-3180, and up to eight with the WOLF-3183, at ultra-high-definition (UHD) 4K resolution. Built on WOLF's proprietary FGX2 architecture, they provide the capability to capture, synchronize, and transmit high-bandwidth video signals in real time, while meeting stringent requirements for latency, power consumption, and signal integrity. For the X-59, this capability is especially critical, as the externally mounted cameras on the aircraft must operate in perfect synchronization to create a seamless and distortion-free composite image for pilot navigation.

The frame grabbers interface directly with a range of video inputs, including 12G-SDI, CoaXPress, analog, and ARINC 818 protocols. Their flexible I/O architecture allows NASA to integrate a mix of commercial and flight-certified imaging sensors, maximizing both visual fidelity and certification compliance. Once captured, video frames are pre-processed for scaling, deinterlacing, and pixel formatting, then forwarded to the next stage in the pipeline for GPU-based rendering. The use of FGX2 technology ensures that these transformations occur with no frame delay, preserving the real-time responsiveness required for dynamic flight conditions, including runway alignment, terrain avoidance, and mid-air adjustments.

Complementing the FGX2 modules is the XMC-E9171-VO (WOLF-3196), a graphics processing and display module that plays a central role in translating raw image data into a human-readable, actionable interface. Powered by an embedded AMD Radeon™ E9171 GPU, the WOLF-3196 supports multi-display outputs and hardware-accelerated rendering of 2D and 3D content. In the context of the XVS, this module is responsible for compositing the multiple incoming video feeds into a single, panoramic synthetic view that replicates the visibility offered by a traditional forward-facing cockpit window.

The GPU's onboard graphics pipeline allows for the addition of flight overlays, navigation markers, and instrument symbology, effectively turning the display into a real-time, visually integrated mission dashboard.

This level of image synthesis is not merely cosmetic. In a supersonic flight environment, where decision windows are narrower and visibility conditions change rapidly due to the environment, the ability to process and present accurate visual information without perceptible delay is a prerequisite for safe operation. The WOLF-3196 meets this challenge with hardware-level acceleration for graphics rendering, low power draw, and a thermal design profile optimized for compact, sealed avionics enclosures. Its design reflects a deep understanding of the unique constraints of airborne computing, including size, weight, and power (SWaP) limitations.

All of WOLF’s modules used in the X-59 QueSST program are purpose-built to endure the extreme operating conditions typical of high-altitude flight. These include rapid and repeated pressure differentials, ambient temperatures ranging from −40°C to 85°C, and continuous exposure to vibration, shock, and electromagnetic interference. Each module undergoes extensive environmental testing and validation, including thermal cycling, MIL-STD-810 qualification, and radiation tolerance assessment where applicable. These ruggedization measures ensure that the hardware can sustain long-term flight performance without degradation, even in the most punishing operational theaters.

WOLF Advanced Technology’s selection for this project underscores its position as a leader in high-reliability, high-performance video processing for aerospace and defense applications. Its XMC-FGX2 and GPU-based display modules offer a powerful combination of modularity, processing power, and durability—three attributes that are essential not only for the success of the XVS but for the broader trend toward digital vision systems in aviation. By integrating these solutions into the X-59 aircraft, NASA has demonstrated confidence in WOLF’s ability to deliver mission-critical technologies that are not only functional but transformative.

In summary, WOLF’s hardware enables the seamless operation of the X-59’s synthetic vision cockpit, playing an essential role in NASA’s effort to redefine the future of supersonic travel. The success of the XVS would not be possible without the precise, rugged, and scalable technology provided by WOLF—technology that bridges the gap between next-generation aircraft design and pilot perception in a world without windows.

HARDWARE MODULE	PRIMARY FUNCTION	TECHNICAL FEATURE	ROLE IN XVS PIPELINE
XMC-FGX2-SDI-4IO	Frame Grabbing	4K video ingest, 4x SDI input	Captures high-resolution video from external cameras
XMC-FGX2-8IO	Multi-Input Frame Grabbing	Up to 8 channels of SDI input	Enables synchronized multi-camera acquisition
XMC-E9171-VO	Video Rendering & Display	AMD Radeon GPU, low-latency rendering	Synthesizes and displays real-time cockpit view

Table 1. Overview of Wolf Advanced Technology modules used in the X-59 XVS system. Each hardware unit plays a critical role in enabling seamless, low-latency visual feeds essential for pilot navigation in the absence of a forward-facing windshield.

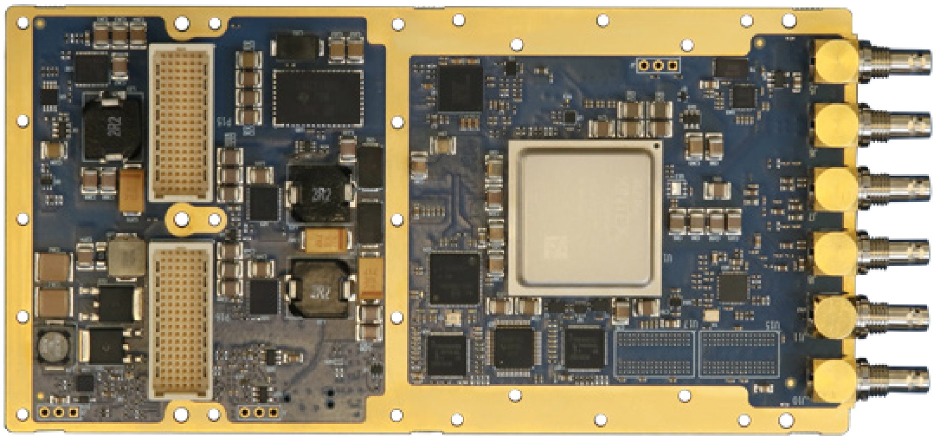

Image 3. WOLF's XMC-FGX2-SDI-4IO (WOLF-3180) module.

IMPACT ON THE MISSION

WOLF's hardware enables the core functionality of the XVS. Without the ability to see forward, the aircraft's mission—and even its basic operation—would not be possible. The seamless integration of WOLF's FGX2 and GPU display modules makes it possible to translate high-bandwidth camera data into actionable visual information in real time. This contributes not only to mission safety but also to the long-term viability of replacing traditional flight visibility systems with electronic solutions.

By supporting the XVS, Wolf Advanced Technology has enabled NASA to pursue a radical design paradigm: a supersonic aircraft that not only avoids the noise impact of a sonic boom but also redefines what cockpit vision can look like in next-generation aerospace vehicles.

STRATEGIC SIGNIFICANCE

Participation in the X-59 project demonstrates WOLF's leadership in the field of aerospace video processing and graphics acceleration. The company's ability to deliver COTS modules that meet NASA's strict performance, size, weight, and power (SWaP) requirements positions it as a key player in future aerospace programs—especially those involving vision systems, AI-based display enhancements, or unmanned vehicles requiring sophisticated imaging.

WOLF's modular hardware is well-suited to scale across both military and commercial applications, from drones and satellites to next-generation airliners. The lessons learned from the X-59's XVS program will inform future efforts to create more compact, efficient, and digitally enhanced vision systems for aircraft with unconventional configurations.

MEETING SWaP DEMANDS WITHOUT COMPROMISE

One of the most critical engineering challenges in modern aerospace systems is the management of Size, Weight, and Power (SWaP). In a testbed as specialized as NASA's X-59 QueSST, these constraints are non-negotiable. Every system onboard must be engineered for maximum efficiency without sacrificing performance, especially when it serves a mission-critical role.
The eXternal Vision System (XVS)—the digital cockpit technology replacing a traditional forward-facing window on the X-59—required sophisticated video processing and real-time rendering, but in a form factor compact enough to fit into an aircraft designed for supersonic flight.

Wolf Advanced Technology delivered on this requirement with a high-performance, rugged embedded solution capable of handling demanding visual workloads under extreme environmental constraints. The WOLF module integrated NVIDIA® GPU acceleration in a compact, conduction-cooled architecture designed specifically for edge deployment. Its reduced footprint and thermal efficiency enabled it to be deployed directly in the aircraft's avionics bay, minimizing cable lengths, simplifying integration, and reducing overall system weight. Just as important, WOLF's hardware met strict aerospace power budgets, ensuring reliable operation without drawing excessive current from the aircraft's limited electrical supply.

WOLF's extensive experience in designing systems for harsh aerospace environments—where heat, vibration, and electromagnetic interference are ever-present—made it possible to deliver high throughput without exceeding the thermal or spatial tolerances of the airframe. This balance of power and restraint exemplifies the essence of SWaP optimization and highlights how WOLF's engineering priorities align with the demands of next-generation aviation platforms like the X-59.

CATEGORY	HIGHLIGHTS
Core Features	FGX2 capture & transmit engine · 2× CoaXPress (CXP-6) · 2× 12G-SDI in / 4× out · Analog & VGA support · DP inputs (up to 1080p) · Low power (12–25W)
Performance	PCIe x8 Gen3 (7.88 GB/s) · Optional 8Gb DDR4 RAM · Windows, Linux, VxWorks drivers · Standalone with Embedded Linux
Rugged Specs	-40°C to +85°C · Vibration: 10G · Shock: 30G/40G · Air- or conduction-cooled · VITA 46.9 compliant
Overview	Next-gen FGX2 with 4K & distributed video, 8× bandwidth vs. previous gen, legacy analog support, new CoaXPress camera inputs

Table 2. The WOLF-3180 with FGX2 delivers next-generation frame grabbing technology—supporting 4K, distributed video, and CoaXPress inputs—while maintaining low power use and rugged reliability for mission-critical applications.

REAL-TIME PROCESSING, REAL-WORLD RELIABILITY

For the XVS to be a viable replacement for a physical cockpit window, it needed to offer the pilot not only a clear and accurate view ahead, but one that is responsive in real time. This challenge is more complex than it appears. Unlike heads-up displays or after-the-fact video recording, synthetic vision systems require the fusion, processing, and display of camera input within milliseconds of capture. Any delay, even a few hundred milliseconds, could introduce disorientation during fast maneuvers or compromise situational awareness during takeoff and landing.

WOLF Advanced Technology's embedded solution offered deterministic, low-latency processing, enabling rapid decoding, enhancement, and rendering of video streams from multiple high-resolution cameras mounted on the aircraft's nose. Powered by NVIDIA® GPU acceleration and supported by high-bandwidth video capture interfaces, the module was capable of handling simultaneous streams with real-time stitching and overlay. This not only ensured seamless pilot visibility but also provided an ideal test environment for NASA's research into pilot perception and cognitive load in next-gen digital cockpits.

What truly sets WOLF's implementation apart is its ability to maintain this performance over time in a flight environment. The ruggedization of the hardware allows for consistent thermal behavior, protecting against thermal throttling or performance degradation during long-duration flights. Additionally, deterministic processing paths reduce variability in frame timing, which is essential in aerospace where predictability is as important as speed. In helping to prove that synthetic vision can safely and reliably replace a traditional forward view, WOLF has demonstrated how real-time embedded computing can serve the future of manned flight.

FROM EXPERIMENTAL TO MAINSTREAM: WHAT COMES NEXT

The inclusion of WOLF's technology in the X-59 QueSST is not just a milestone for the company—it signals a broader evolution in aerospace system design. With the successful integration of a windowless cockpit powered by ruggedized, GPU-accelerated vision systems, NASA and Lockheed Martin are charting a path toward more efficient, streamlined, and sensor-driven aircraft. As synthetic vision becomes validated in supersonic applications, its adoption is poised to expand into mainstream aerospace, first in military and experimental craft, then in commercial aviation and urban air mobility platforms.

In this context, WOLF's modular, edge-deployable compute solutions are uniquely positioned to meet the needs of future airframes. Beyond vision processing, these modules can be adapted to support AI-based navigation, threat detection, autonomous mission management, or predictive maintenance systems—all of which require local processing power in tightly constrained environments. The scalable nature of WOLF's technology ensures that as mission needs evolve, so too can the capabilities of the onboard compute stack, without requiring a redesign of the aircraft systems architecture.

Looking ahead, WOLF continues to invest in next-generation form factors, AI acceleration, and high-speed connectivity to stay ahead of industry needs. The company's involvement in programs like the X-59 not only affirms its engineering excellence, but also sets the stage for long-term contributions to the next era of flight—where speed, sustainability, and digital intelligence converge.

NEWEST DEVELOPMENTS

NASA's X 59 Quiet Supersonic research aircraft has recently reached a new milestone within the project timeline. On July 10, 2025, it successfully completed its first low speed taxi test at U.S. Air Force Plant 42 in Palmdale, California. During this initial ground run, engineers and flight crews validated critical systems like steering and braking as the jet moved under its own power. This was the final series of ground tests before progressing to high speed taxi trials just shy of takeoff.

Over the coming weeks, the team will advance to high speed taxi tests, gradually increasing runway speeds to verify performance and prepare for X 59's first flight, expected later this year.

Image 4. NASA test pilot Nils Larson, alongside the X-59 team from NASA and Lockheed Martin, conducting the aircraft's first low-speed taxi test on July 10, 2025 in Palmdale, California.

CONCLUSION

WOLF Advanced Technology's involvement in NASA's X-59 QueSST program marks a significant milestone in the company's ongoing mission to enable high-reliability, high-performance computing in extreme environments. Through its FGX2 and GPU display modules, WOLF has played a vital role in replacing the conventional cockpit windshield with a fully digital, real-time vision system—helping to make the dream of low-boom supersonic travel a reality. As NASA and Lockheed Martin prepare for community flight tests and future commercialization, WOLF's contribution remains central to the safe, effective operation of this revolutionary aircraft.

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