Brüel & Kjær
BEYOND MEASURE

LOCKHEED MARTIN'S F-35 RAMP NOISE AND DURABILITY TESTS

To ensure the high performance of some of the most technologically sophisticated machines ever built, Lockheed Martin turned to Brüel & Kjær. In order to help protect ground crew working on aircraft carrier decks, Brüel & Kjær supplied a complete solution for acoustic characterization. Vibration test systems provided durability assurance and stress screening.

LOCKHEED MARTIN

CHALLENGE

- Protect ground crew personnel from extreme noise levels
- Ensure structural integrity under high stress

SOLUTION

- Ramp noise testing with transducers, data acquisition systems, and workflow-tailored analysis software, supported with domain expertise
- Reliable vibration test systems

RESULTS

- Data captured right-first-time and processed for same-day result confirmation, giving greater test flexibility and data confidence
- Effective ground crew protection measures
- Assured durability of components and sub-assemblies

BACKGROUND

Lockheed Martin is an American global aerospace, defence, security and advanced technology company with worldwide interests, which employs 112,000 people worldwide. Its core business areas include aeronautics, missile and fire control, and space systems. Its latest, cutting-edge fighter – F-35 Lightning II – is being manufactured in Fort Worth, Texas – famous for its frontier atmosphere.

Creating an unprecedented fighter jet takes unprecedented collaboration and many different global partnerships have helped to create the world's only international, fifth generation, multirole fighter. Lockheed Martin uses specialized domain expertise across all of its core business areas. The F-35 programme includes rigorous noise analysis tests of the newest fighter jet, and extensive durability testing. Brüel & Kjær has been helping with acoustics, and complex vibration testing to ensure the integrity and reliability of fighter jets, missiles and satellites.

In a world where speed and power dominate, tight development schedules mean that time is critical. The complex and expensive test objects are not always readily available and often require massive resources, so it is imperative that testing is successful the first time. Noise analysis and vibration testing within the aerospace and defence industry must be accomplished in a short time window and produce accurate data that is stored safely and securely.

CHALLENGE

Different variants = different acoustics

All variants of the F-35 Lightning II use the world's most powerful fighter engine, the Pratt & Whitney F135. One of the goals of the testing was to establish the acoustic footprint of the three F-35 variants, under all relevant operational conditions from take-off, landing, taxiing and fly-over, to the most challenging of them all: hovering.

The F-35 – the most powerful single-engine fighter ever built

A multirole fighter is designed to excel in multiple combat missions. The F-35's roles include air-to-air; air-to-ground; intelligence, surveillance and reconnaissance; electronic attack; and command and control. Using a combination of design, tactics and technology, the F-35 has advanced stealth capabilities, making it virtually undetectable. The integrated avionics and comprehensive sensor package give pilots real-time, 360-degree access to battlefield information.

The F-35 is manufactured in three versions:

- F-35A conventional take-off and landing (CTOL)
- F-35B short take-off/vertical landing (STOVL)
- F-35C carrier variant (CV)

Vital statistics:

- Height: 14ft
- Length: 52ft
- Wingspan 35ft (F-35A and F-35B) and 43ft (F-35C)
- Max. speed: in excess of Mach 1.6
- Engine: a single Pratt & Whitney F135, producing approximately 40,000 pounds of thrust in afterburner
- Weight: approximately 60,000 lbs (gross)

Occupational noise exposure

Although military aircraft are not obligated to fulfil the ramp noise requirements stipulated by civil aviation authorities, Lockheed Martin's F-35 programme carries out testing to protect personnel. For the F-35B variant, the short take-off and vertical landing functionality gives the unique ability to operate from a variety of ships, roads and frontline combat zones, providing flexibility in many scenarios.

However, noise exposure is a challenge for ground personnel who work in close proximity to this aircraft, especially on aircraft carrier decks. Here the fighter jet comes in vertically (which requires a lot of power) and the support crew can be standing below it, therefore getting more noise exposure compared to a conventional take-off/landing.

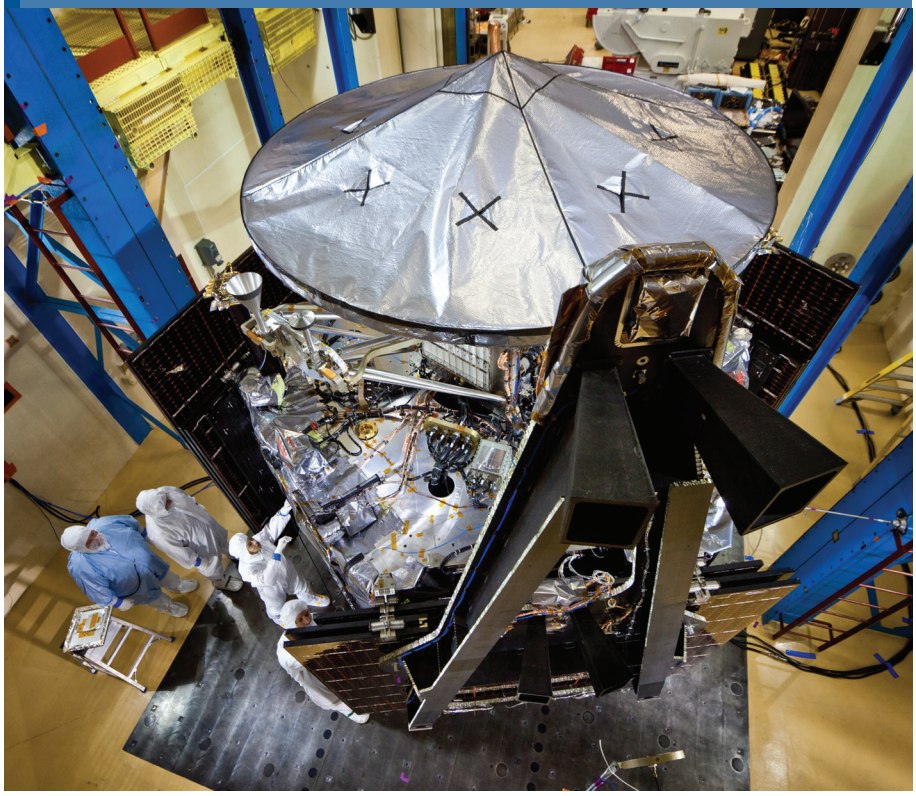
Capturing accurate data without fail is critical to take advantage of limited opportunities in an extensive programme.

Durability testing and quality control

In addition to noise challenges, extensive qualification tests are needed for durability testing, stress screening and R&D qualification testing of aircraft components and sub-assemblies.

Ensuring space systems survive lift-off

Fighter jets, missiles and satellites all undergo extensive vibration testing. For space systems, Lockheed Martin's LDS shakers test to ensure that the different components can survive the rigours of a launch, deployment, transport, and long-term operation. Recording the data is a critical component of vibration testing and data acquisition is needed to measure what's going on in, for example, satellites and components at launch. Due to the high cost and complexity, satellite vibration qualification tests are among the most monitored and carefully run tests in the world. Vibration tests are often run with hundreds of channels of simultaneous data acquisition and multi-shaker tests are often run on extremely large payloads or for a multiple degree of freedom simulation.



SOLUTION

Ramp noise solution

As part of the F-35 programme, Lockheed Martin began by using a ramp noise solution based on Brüel & Kjær's PULSE LabShop platform, which was later supplemented with the Reflex post-analysis software. This integrated solution involves 75 microphones being laid out over the runway. The noise signals are collected by high-performance data acquisition hardware and the data is delivered to powerful analysis software, where the measurements can be easily reviewed and analysed.

Lockheed Martin is using approximately 450 LAN-XI channels for vibroacoustic data acquisition. Based on standard, modular, commercial- off-the-shelf PULSE LAN-XI Data Acquisition Hardware, the flexible solution allows for individual modules to be used freely – either by themselves in the lab or test centre, or alternatively mounted together in a large frame. Depending on test requirements, Lockheed Martin can take a module out of a frame and use it in the control room or in whatever way that suits the test best. This flexible solution makes it ideal for testing large structures, such as satellites and spacecraft.

The high number of channels supported, high data-sampling frequencies, tight phase matching between channels, and the ability to handle a wide dynamic range of inputs all make the PULSE solution ideal for large aerospace systems. Self-test and verification tools are dedicated to high channel-count systems, which ensure reliable performance, even in the most complex configurations.

Vibration test solutions

Lockheed Martin has been putting the F-35's systems through exhaustive vibration test programmes and some of Brüel & Kjær's large V9x water-cooled Shakers (V984 and V994) are being used, for example, to test missiles and fire control in Lufkin, Texas.

Protecting ground crew from ramp noise

Civil aviation authorities require ramp noise testing but it is not a military requirement. The F-35 programme, however, carries out ramp noise testing to protect personnel from noise exposure.

- Used traditionally for civil aircraft when parked on the runway since aircraft can still be noisy, even when only auxiliary engines are running
- Evaluates the noise exposure of aircraft personnel and ground crew
- Maps where the noise is coming from and the noise patterns
- High-quality testing has greater significance as new materials and new designs are assessed for exterior noise

RESULTS

Data successfully acquired

The data acquisition solution was used to seamlessly acquire and analyse a large amount of data for all F-35 variants under different conditions, establishing the various noise footprints and helping to ensure noise exposure is limited within all these environments. These results are used to inform decisions about the right hearing protection for ground crew and, for example, to define areas around the aircraft where certain actions should not occur.

CONCLUSION

Lockheed Martin works with leaders within their fields across the world, resulting in the most advanced solutions. In this demanding environment, reliability and high performance are paramount, and comprehensive noise and vibration measurement and analysis solutions must provide accurate and fast results. Joining forces with the world leaders in acoustic and vibration testing is a successful collaboration that has been ongoing for more than a decade.

This is a partnership where both sides have benefitted from sharing experience and working with the most advanced products – within challenging design and development timeframes. Together, highly skilled noise and vibration experts have addressed some of the most advanced engineering needs around, tackling analysis and measurement of the most sophisticated satellites, missiles and fighters the defence industry has ever manufactured.

Similar to a helicopter that before landing can fly stationary, just above the ground, the F-35B short take-off/vertical landing (STOVL) variant has the ability to hover

This is made possible through the Rolls-Royce patented shaft-driven LiftFan® propulsion system and an engine exhaust nozzle that can swivel 90 degrees when in short take-off/vertical landing mode. The Rolls-Royce LiftSystem® is the first to enable STOVL operations for super-sonic-capable aircraft

Ground grew working in close proximity to these jets are exposed to more noise than with a conventional take-off/landing

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BN 1588 – 11 2015-10

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