SOUND AND VIBRATION NEWS

WAVES

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HOW TO MAKE STAR WARS SOUNDS

JAPAN'S FIRST REGIONAL PASSENGER JET

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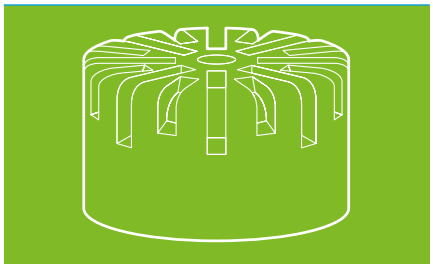

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FRONT COVER IMAGE
Kappa FuturFestival 2018, Turin, Italy

Brüel & Kjær
BEYOND MEASURE

LETTER FROM OUR PRESIDENT

A WORLD ON THE MOVE

As the pace of change increases around the world, Brüel & Kjær continues to help customers keep up with emerging trends and technologies, meet stringent regulations, and ensure consumer acceptance, all the while ensuring safety and enabling a more comfortable environment.

Helping create the right sense of drama, comedy or action at the right moment, Tim Nielsen, Supervising Sound Editor and Sound Designer with Skywalker Sound, has been incorporating some non-traditional 'audio' transducers – in a galaxy far, far away.

Noise monitoring continues to be important, not just within cities but in the skies above them, too. For example, Japan's first commercial aircraft, the Mitsubishi Regional Jet (MRJ), is currently in the certification phase. MRJ aims to offer advanced energy efficiency and aerodynamics, as well as superior passenger comfort. Read about how we are helping MRJ meet the requirements for safety, functionality and noise.

Staying in Japan, we've been assisting the Japan Aerospace Exploration Agency (JAXA) to redesign a launchpad to deflect extreme sound pressure away from the payload during launch. In the same light, mitigating noise without compromising performance is a crucial focus point for Material Sciences Corporation in Michigan, USA, where they are working with Ford Motor Company to support brake-noise testing.

One person's awesome concert is another person's nuisance. The ongoing MONICA project helped bring together a spectacular outdoor concert in Italy, while at the same time, minimizing the noise disturbance in the surrounding environment. The solution enables more accurate control, both for a quality sound experience and limiting sound propagation outside the venue.

Finally, the Brüel & Kjær and Hottinger Baldwin Messtechnik (HBM) merger will unite all the tools needed for a complete testing solution into one company: HBK (Hottinger, Brüel & Kjær). HBK will consolidate our combined domain expertise into one discipline called product physics, enabling us to provide our customers with the insight and confidence they need to create outstanding products in a digital world.

We're looking forward to the future!

SØREN HOLST
PRESIDENT

PREPARING FOR TAKE-OFF: JAPAN'S FIRST REGIONAL PASSENGER JET

AIRCRAFT CERTIFICATION REQUIREMENTS

Certification requirements for civil aircraft are derived from the International Civil Aviation Organization (ICAO). Each ICAO contracting state then establishes its own legal framework to implement the internationally agreed standards and recommended practices.

Scheduled for first delivery in 2020, Japan's first commercial jet aircraft, Mitsubishi Regional Jet (MRJ), is in certification phase. The aircraft is highly anticipated and is a huge source of pride for the country.

After World War II, as part of its occupation of Japan, the US prohibited any aircraft research and development and split the major aircraft companies into smaller enterprises. This lasted until 1952, when Japan regained its sovereignty and resumed its authority to manufacture aircraft.

As the Japanese aerospace industry matured, it focused primarily on military aircraft and supplying critical, complex structures to global players such as Airbus and Boeing, including building a third of Boeing's 787. In 1964, Japan attempted to compete in the commercial aircraft market with its YS-11, but due to a combination of economic and political issues, the business was unprofitable and production of the YS-11 was ended in 1972.

Nevertheless, co-production with American and European manufacturers has continued to stimulate the development of Japanese aircraft design and engineering. According to industry analyst Richard Aboulafia, focusing on a broad portfolio of important technologies instead of building an aircraft has, in many ways, been the secret of Japan's success. Although the market is already dominated by two players, Brazil's Embraer and Canada's Bombardier, neither of whom are willing to concede territory, many experts believe the MRJ will be a success. The jet made its first public demonstration flight in July at Britain's Farnborough International Airshow 2018 and has already racked up 387 orders.

THE COMEBACK STRATEGY

After the disappointment of the YS-11, the government of Japan developed a strategy for its civil aircraft industry that, besides joint ventures with international manufacturers, involved forming a consortium of Japanese aircraft manufacturers for developing and producing new aircraft and providing government financing for aircraft R&D programmes.

JAPANESE DESIGN, CRAFTSMANSHIP AND QUALITY

Japan is renowned for its technological prowess, but the country also has a strong tradition of aircraft design, going all the way back to pre-World War II and Jiro Horikoshi, who is known to many as the father of Japanese aircraft design.

Born in 1903, Horikoshi began experimenting with aircraft design at the University of Tokyo and in 1936, as an employee of Mitsubishi Heavy Industries (MHI), his first successful aircraft, the Mitsubishi A5M, went into mass production. In 2013, Horikoshi was immortalized by animation master Hayao Miyazaki in his film The Wind Rises, a fictional animated biography that follows the progression of his designs. ▶

Mitsubishi Aircraft Corporation (MITAC) is 64% owned by MHI, and Toyota Motor Corporation and Mitsubishi Corporation each hold a 10% stake

PREPARING FOR TAKE-OFF: JAPAN'S FIRST REGIONAL PASSENGER JET

Roll-out event held on 18 October 2014 at MHI's Komaki-Minami factory in Aichi. This was the first unveiling of the MRJ

Along with a strong design tradition, Japan has many famed business practices that focus on doing things the right way, such as total quality management (TQM), Kaizen (continuous improvement) and Monozukuri, which literally means 'production' or 'making things'. Monozukuri also embodies a synthesis of technological prowess, know-how and spirit of Japan's manufacturing practices.

Monozukuri could be characterized as more of a philosophy than a technique or method. It underlines that manufacturing should be in harmony with nature and should be of value to society. When an item or human effort is used, the balance between production, resources and society should be maintained. Monozukuri also encourages workers to 'bring their mind to work'. They are fully empowered and trained to deal with different situations creatively. This creates an elevated sense of ownership and instils a sense of pride and passion for the work.

The combination of these design, engineering and manufacturing traditions is hard at work on the MRJ, which will be produced at Komaki Airport in Nagoya, Japan. The new plant will produce ten aircraft per month.

> "ANY DATA THAT NEEDS CRUNCHING, ENGINEERING THAT NEEDS TO BE WORKED OUT, WE CAN HAND IT OVER TO JAPAN AND THEY CAN TAKE A STAB AT IT WHILE WE'RE ASLEEP."
>
> OPERATIONS SUPPORT ENGINEER
> MITSUBISHI REGIONAL JET

WHAT MAKES THE MRJ DESIGN SPECIAL?

With the goal of achieving advanced energy efficiency and aerodynamics and superior passenger comfort, the MRJ started with a clean-sheet design. The engine is Pratt & Whitney's Geared Turbofan™, which is optimized specifically for the MRJ and burns a fifth less fuel than an aircraft of similar size. At the same time, the combination of a streamlined nose, low-drag fuselage, low-drag tail cone and optimized wing and engine configuration increases fuel efficiency and makes for a smoother, more fluid ride.

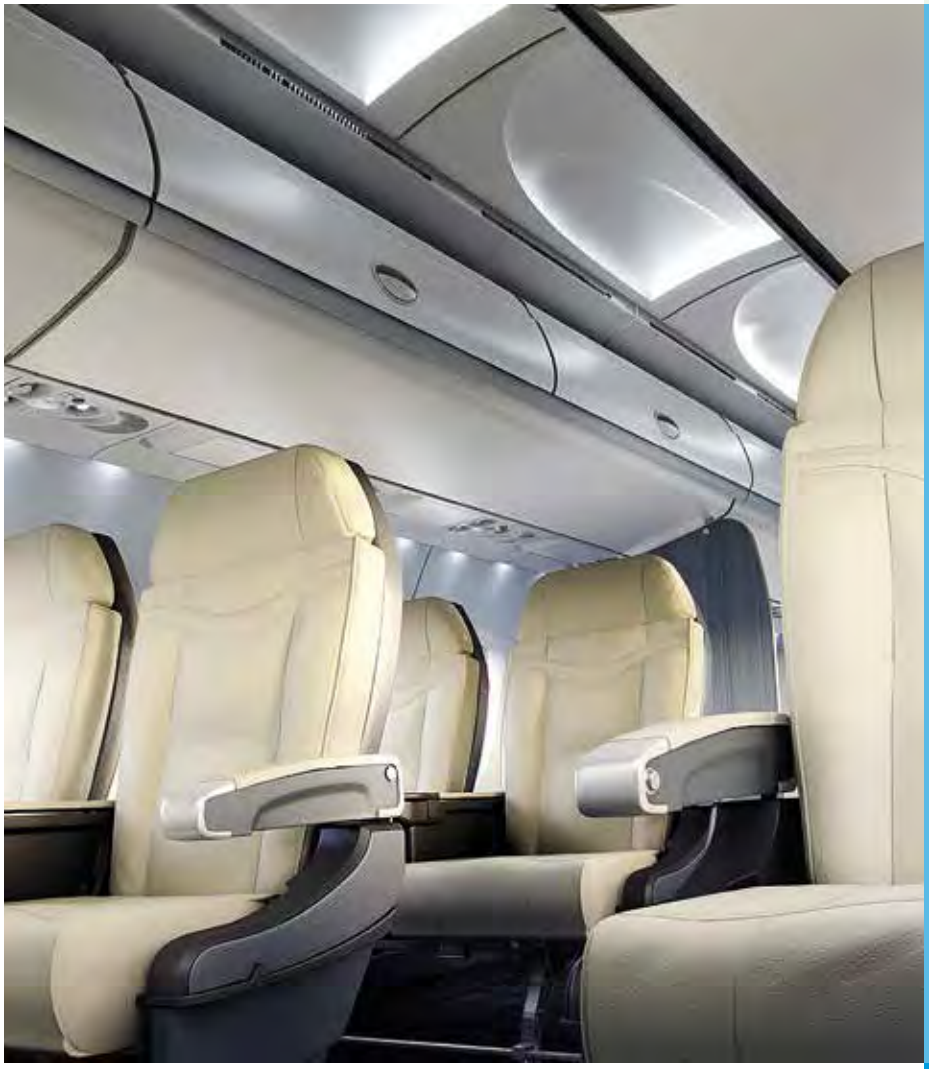
In the cabin, Mitsubishi Aircraft Corporation (MITAC) also started with a clean sheet. They took the cargo hold out of the belly to increase passenger space and widened the seats and aisles. That means a generally more spacious cabin and more legroom. They also expanded the overhead bins and added LED lighting for a more relaxed and comfortable flying experience.

The combination of the latest engine technology and advanced aerodynamics technology greatly reduces noise at take-off and landing, compared to conventional airplanes. Noise levels are expected to be significantly lower than the ICAO regulations require.

THE CERTIFICATION JOURNEY

Currently in the certification phase, MITAC is conducting a series of tests at Moses Lake testing facility near Seattle, including tests for safety, functionality and noise. The Moses Lake engineering team works closely with another engineering team in Nagoya, Japan that allows for a constant flow of communication. "Any data that needs crunching, engineering that needs to be worked out, we can hand it over to Japan and they can take a stab at it while we're asleep," says one of MRJ's operations support engineers.

One of MRJ's top certification priorities is the ICAO Annex 16 exterior take-off and landing noise test. Noise measurements are made on the apron. ▶



To evaluate cabin noise, MRJ uses Brüel & Kjær's sliced wheel array and hand-held array, both of which are mounted with multiple microphones, to perform noise source identification (NSI)

PREPARING FOR TAKE-OFF: JAPAN'S FIRST REGIONAL PASSENGER JET

For measuring noise on the apron, LAN-XI modules are distributed on the ground, enabling faster multichannel measurement across a wide area with fewer engineers. During ramp noise testing on the ground, the LAN-XI modules must not be too close to the aircraft, so extended LAN cables make it possible to effectively record and make real-time measurements under the aircraft body.

To evaluate cabin noise, MRJ uses Brüel & Kjær's sliced wheel array and hand-held array, both of which are mounted with multiple microphones, to perform noise source identification (NSI). With NSI they can test for leakage of noise into the cabin through the cabin wall and interior trim. This helps identify areas of the aircraft that need continued analysis or further design. For any other on-site noise or vibration measurement, LAN-XI can be used for investigating any issue, as it is easy to transport from place to place to make quick real-time measurements. This helps keep the development of the aircraft on schedule.

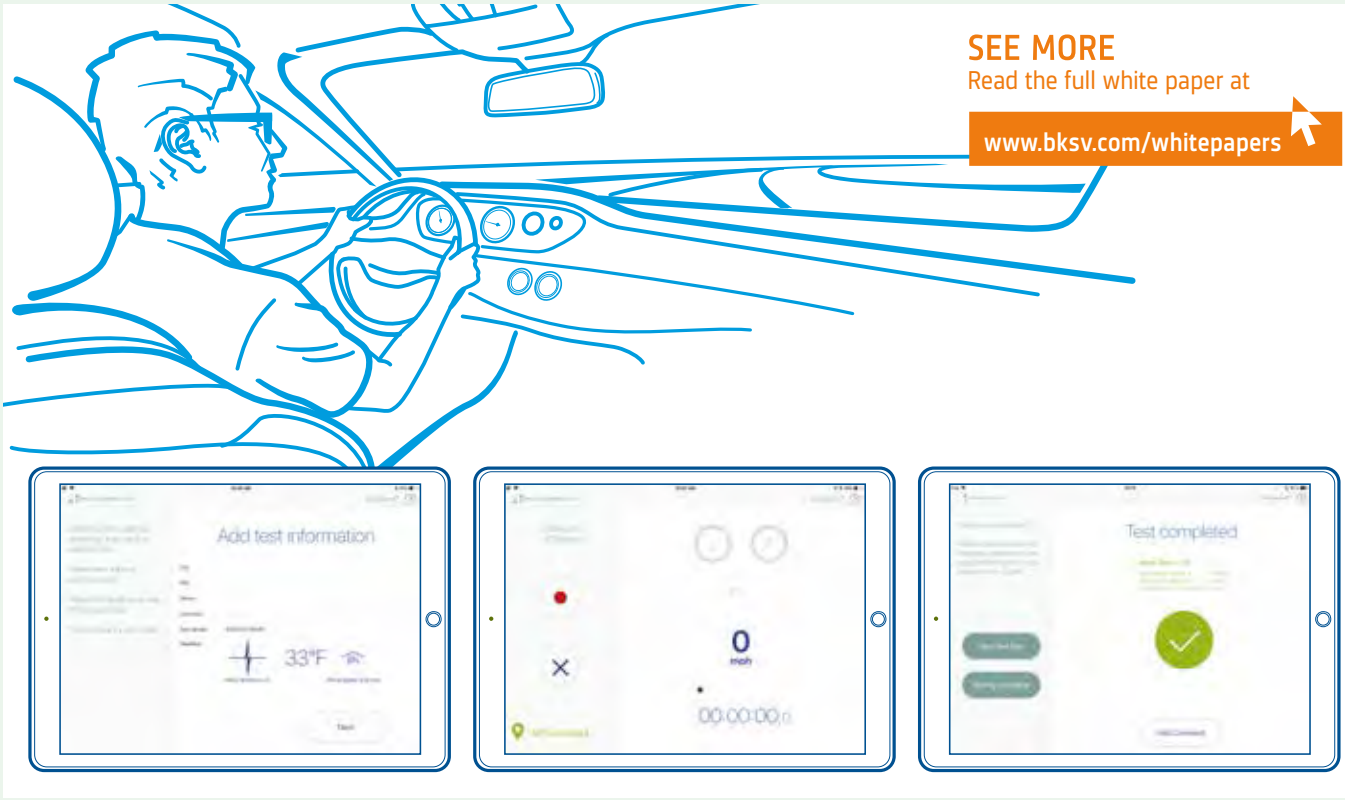
Meanwhile, the people of Japan eagerly anticipate their first commercial passenger jet, the opportunities it will afford and the country's long-awaited return to the commercial aircraft industry.

IT ALL STARTED IN SHIPBUILDING

In 1884, the founder of Mitsubishi, Yataro Iwasaki, took out a lease on the government-owned Nagasaki shipyard and started a full-scale shipbuilding business. Later the business became Mitsubishi Shipbuilding Co. and launched as Mitsubishi Heavy Industries in 1934, establishing its position as the largest private firm in Japan, manufacturing ships, heavy machinery, railroad cars and aeroplanes.

A NEW WHITE PAPER FROM THE STACKS

A NEW APPROACH TO END-OF-LINE VEHICLE AUDITING – TURNING SUBJECTIVE EVALUATIONS TO OBJECTIVE RANKINGS USING A NEW SIGNAL PROCESS ALGORITHM



To enable the identification of production issues, a portable analysis system has been developed to complement the subjective impression of the audit driver by automatically producing objective data that can be used to diagnose and solve problems.

In a production plant environment, the traditional method of auditing build quality is for drivers to subjectively evaluate the final product in real-life driving conditions. In the case of in-cabin wind noise, this is difficult and unrepeatable because of weather, traffic and varying road conditions. If a driver has a negative subjective impression at the end of the test route, the vehicle is held for further evaluation and further checks by a wind noise expert at the plant. However, wait times for evaluation can be long and lead to delays in resolving any problems.

To address these issues, and to increase the pace at which the root cause of wind noise concerns can be identified and remedied in the manufacturing process, a portable tool, the Sonoscout Vehicle Audit System (Sonoscout VAS) has been developed. Sonoscout VAS is specifically designed to seamlessly integrate into existing processes. When applied, the system can quantify the wind noise performance of a vehicle in a real-world environment, acquire repeatable, objective data and provide real-time results on the performance of the vehicle.

The algorithms implemented in Sonoscout VAS allows OEMs to automate data acquisition, assess the quality of the data, compute wind noise metrics and produce pass/fail results based on sound quality metrics and a frequency-based octave analysis. All this when the vehicle is driven by a non-NVH trained operator over public roads.

NOT SO LONG AGO
IN A MOVIE RIGHT BY YOU....

The sound of explosions, vehicles, weapons, rustling trees and even breathing – in one famous case – are carefully orchestrated elements that can make or break the audience's immersion. But particular real-life noises might be kind of underwhelming, so where does that perfect sound come from?

> "WHEN I START A JOB, I NEVER HAVE IT FIGURED OUT BEFOREHAND. EVERY JOB IS A NEW EXPLORATION OF SOUND."
>
> TIM NIELSEN
> SUPERVISING SOUND EDITOR AND
> SOUND DESIGNER WITH SKYWALKER SOUND

The new blaster sounds in 'Solo: A Star Wars Story' were recorded with accelerometers because of their flat extended frequency range

Just about everyone in the world knows Star Wars. And there are diehard fans who know all about each of the movies (not to mention the extended universe), from the number of AT-AT walkers in the battle for Hoth to the meanings of lightsaber colours, and all of them familiar with the different sounds (created by the brilliant Ben Burtt) in the Star Wars universe. Some might argue one way or another about being able to hear explosions in a vacuum or propulsion systems screaming through space, but the movies wouldn't be the same without them – from the Millennium Falcon to Tie fighters – those sounds are iconic. As, too, is the sound of that good blaster at the side of the title character in the latest installment – Solo: A Star Wars Story.

THE SOUND?

Sound is a bargain for film makers. For example, the look and texture of the T-1000 from Terminator 2 may have cost millions, but the sound of it oozing from one form to another comes from a dog-food can. That's not to diminish the development of sound. Sound designers are constantly on the lookout for interesting sounds, and the importance of the right sound going with the right visual can be illustrated by trying to imagine a different sound for a lightsaber – it just wouldn't be the same. The visual and the audial need to be just right. And because they never know how much a particular sound might be reused or useful for something else in the future, sound libraries are extensive and ever-growing.

You can envision sound engineers walking through junk yards smacking things, and you wouldn't be far off. The sounds you hear, disassociated with the object with which you would be familiar, are often not as altered as you would think. ▶

NOT SO LONG AGO
IN A MOVIE RIGHT
BY YOU....

> "THE MAJORITY OF THE SOUNDS I USE ARE VERY CLOSE TO THE ORIGINAL RECORDING."
>
> TIM NIELSEN
> SUPERVISING SOUND EDITOR AND SOUND DESIGNER WITH SKYWALKER SOUND

Objects and their environments are manipulated for the unique sound they can produce rather than the sound being manipulated later in the studio. As Tim puts it: "It is extremely important to have the cleanest recording of the sound that is possible." What the sound engineer hears and records needs to be the same sound when it is played back later; otherwise, it may not become that perfect joining of sound to sight.

YOU'VE SWITCHED OFF YOUR PROCESSING COMPUTER

It's important to have the right equipment to get the most accurate recording of the object as possible. The idea is to manipulate the environment to get a sound that the object wouldn't ordinarily make – like using your surroundings as an instrument.

Tim points out that, "This is a concept that many beginning sound designers don't get. When you start post-processing to get sounds, the processes are too related, so the sounds pick up too much of the same quality and start to muddle together and lose their individuality."

The new Solo movie introduced a multitude of new sounds, particularly blasters, and in honour of Ben Burtt (the original Star Wars sound guru), Tim wanted to use similar sound sources to achieve the new sounds. However, the new sounds needed to have their own character, not just to be different, but also to ensure that the iconic sound of Han's blaster stays iconic. So the challenge was to get the new sounds without processing them extensively.

"The industry traditionally uses a variety of contact microphones to capture mechanical noise, which can be cool, but transition to accelerometers enables a cleaner recording."

Normally, contact microphones are attached to an object and that object is manipulated or excited in some way to produce a sound that is recorded and stored. The more robust accelerometer, however, compared to the thin piezoelectric contact microphone, provides a cleaner sound with much higher fidelity and a greater frequency range. Tim reached out to Vince Rey of Brüel & Kjær, and together they sampled an assortment of accelerometer and preamplifier combinations until they found the combination that worked the best. They were looking for the perfect balance of noise floor versus sensitivity. The combination of Miniature Hex CCLD Accelerometer Type 4519 and 2-channel Battery-powered CCLD Signal Conditioner Type 1704-A-002 fit the bill perfectly.

"I was introduced to the concept by a friend who introduced me to Jacob Kirkegaard, a Danish sound artist who uses accelerometers to record amazing sounds."

THE SOUND WILL BE WITH YOU, ALWAYS

The new blaster sounds in Solo were recorded with accelerometers. Their flat extended frequency range enabled Tim to get the best version of the sound he was looking for. Of course, not all of the blasters in the movie were recorded with accelerometers because, as Tim earnestly stated, "…you don't want to mess with Star Wars fans." To noticeably change iconic sounds like the Millennium Falcon or Han's blaster would be a really bad idea. That is not to say they have been untouched since their creation (over 40 years ago). For example, in order for Han's blaster to not sound out of place against the new recordings, the frequency range needed to be extended a bit for the movie. But to ensure that both the iconic and new sounds remain just as they should, they are safely locked away, unaltered in the Skywalker Sound library, patiently waiting to sound again.

Tim Nielsen is a Supervising Sound Editor and Sound Designer with Skywalker Sound. His most recent project was the film Solo: A Star Wars Story

EXPERT PROFILE

FINDING PASSION IN THE PERCEPTION OF ACOUSTICS

Growing up in Pune on the west coast of India, the young Sunil Bharitkar watched Indiana Jones movies and aspired to be an archaeologist. But a natural gravitation towards science and math combined with good grades, saw him follow in his father and older brother's footsteps into the world of engineering.

Why do you do what you do?

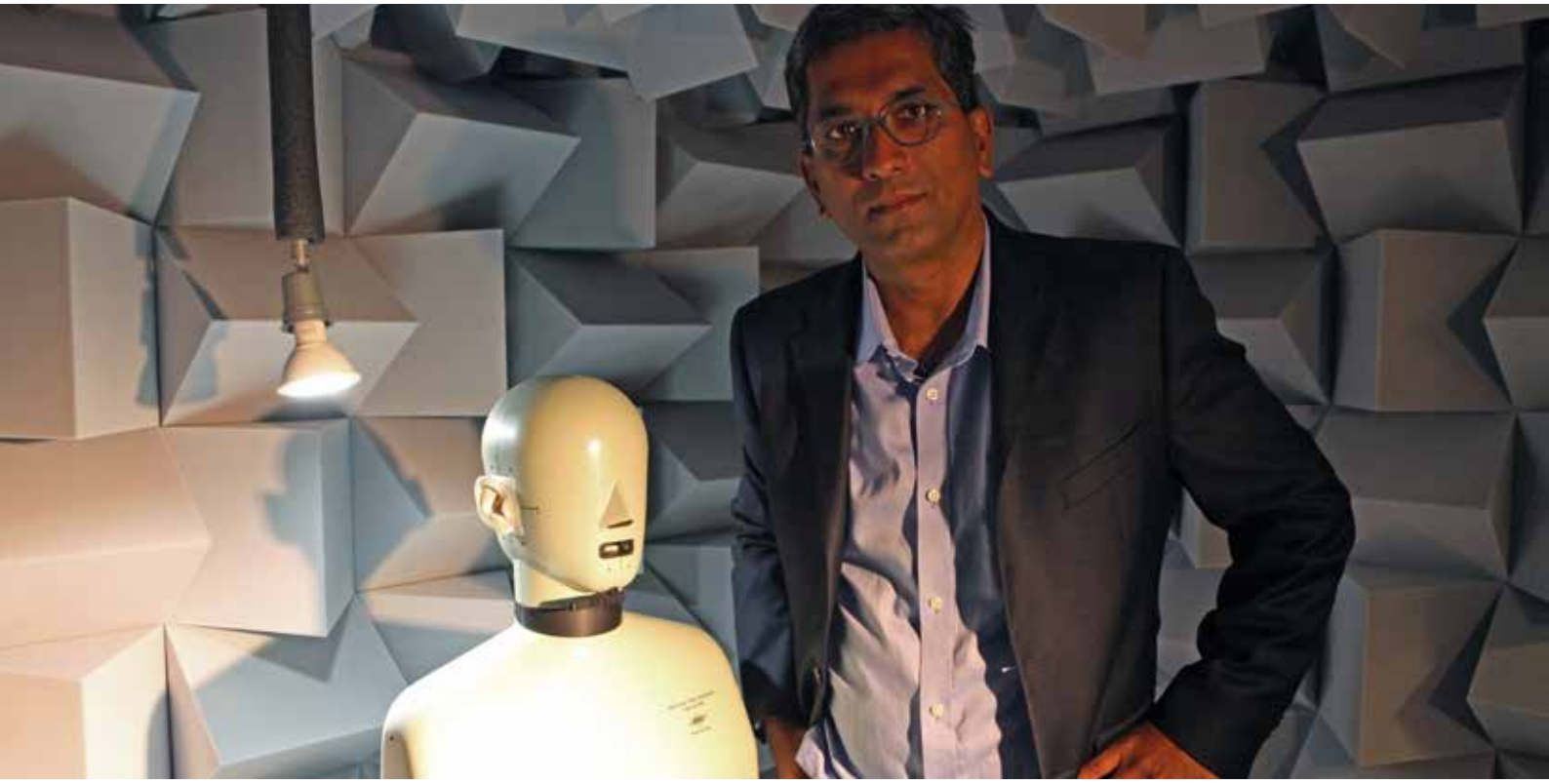
My career grew on me rather than the other way around of "find your passion". During my MS and PhD work, I focused on signal processing (for acoustics/audio/speech) and machine learning (in particular, neural networks and statistical pattern recognition). I enjoy the creativity involved in overcoming challenges for problems in various disciplines (acoustics, perception, life sciences, speech/language) by using signal processing and machine learning.

What or who put you on this path?

During my PhD, I was introduced to an audio class by my soon-to-become doctoral advisor Prof. Chris Kyriakakis. The class was very well taught by him and I felt it had a lot of open problems to research and come up with unique solutions applying signal processing, cognition, and pattern recognition to help better generalization (over a space – rooms/humans). ▶

Sunil Bharitkar is a big fan of music and playing instruments and started with the Indian tabla. These days he plays a didgeridoo that he imported from Australia

FINDING PASSION IN THE PERCEPTION OF ACOUSTICS



"I NOTICED A REGULAR TREND IN TERMS OF WHAT RESEARCHERS WERE DOING FOR IMPROVING AUDIO RENDERINGS, BUT WHAT WAS NOT SERIOUSLY INVESTIGATED WAS THE INFLUENCE OF ROOM, REVERBERATION AND LOUDSPEAKER ACOUSTICS IN AUDIO RENDERING."

SUNIL G BHARITKAR
DISTINGUISHED MEMBER OF TECHNICAL STAFF, EMERGING COMPUTE LAB (ECL), HP LABS

What are the unique challenges you face in your work?

At Hewlett Packard Labs® (HP Labs), the research is incredibly diverse. Not only am I addressing problems in VR spatial audio and Immersive Audio (IA) rendering in ECL, but also audio classification, speech analysis, modelling and representations of cyber-physical systems, life sciences (early cancer detection) with Print Adjacencies and 3D Print Lab, EEG signal analysis and interpretation (with Immersive Experiences Lab), developing AI models for Hollywood content, etc. Brüel & Kjær's Head and Torso Simulator is frequently used for a number of these important projects – both from an in-ear signal capture and a speech reproduction perspective. The HATS system allows perceptually and acoustically relevant measurements, while allowing consistency and reproducibility.

What are the most challenging and rewarding things about what you do?

The most challenging aspect for me involves converting research into technologies that matter. The rewarding aspect is having the

SUNIL G BHARITKAR

Company and Job Title: Distinguished Member of Technical Staff, Emerging Compute Lab (ECL), HP Labs
Location: Palo Alto

EDUCATION

2004:	PhD in Electrical Engineering-Systems, University of Southern California (USC)
1994:	MS Electrical Engineering & Applied Physics, Case Western Reserve University (CWRU)
1991:	BE in Electronics & Telecommunication Engineering, University of Pune

CAREER

2011 – 2016:	Dolby Labs, Director of Audio Technology, Office of the CTO
2002 – 2010:	Audyssey Labs., Co-founder and VP of R&D
1996 – 2004:	Research Assistant/Teaching Assistant, USC
1998 – 1999:	Member of Technical Staff, Ford Motor Research Labs
1991 – 1994:	Research Assistant/Teaching Assistant, CWRU
1994 – 1994:	Visiting Researcher, Keio University, Japan

opportunity to work with a diverse group of extremely bright and talented people, with experience ranging from labs to strategies, and see these technologies go into HP products. I also get to work on some blue-sky projects and fundamental research that does not necessarily have immediate business impact but could end up seeing the light of day in the mid- to long-term.

Share a turning point or defining moment in your work

The defining moment for me was seeing Audyssey Labs™, with its foundations built around the core technology of room acoustic equalization (MultEQ®), spun out from USC. MultEQ was a product of my PhD research, and is now deployed in millions of products from professional (IMAX®) to consumer (Denon®, Onkyo®, Sharp® and Audi®, for example).

Any personal ambitions/goals unattained?
A dream job, mission or vision?

I would like to travel a bit more to experience different cultures and continue my scuba-diving adventures. Now, that our five-year-old twins (Ariana and Ashwin) are easier to travel with, my wife Laurie and I have started vacationing. We are hoping to make a trip to Barcelona in the next few months.

Is there one person who has inspired you in your life and explain why?

My dad was a key person who shaped my future in terms of my early career choice. He juggled both family and work life quite well, despite being a CEO for a multinational engineering company. I remember seeing him bring his work home every day (when he was not travelling abroad) and only getting to it after spending his evening completely with us, and only after we all went to bed. He was the last to go to bed and the first to wake up. I admired his dedication to work and his ethic.

Audyssey is in the homes of a substantial percentage of home theatre owners, what initially drew you to think about how sound is perceived by individuals?

Attending various Audio Engineering Society and Acoustical Society of America conferences, I noticed a regular trend in terms of what researchers were doing for improving audio renderings, but what was not seriously investigated was the influence of room, reverberation and loudspeaker acoustics in audio rendering. The research I spearheaded led to MultEQ and a Best Paper Award at the 2003 37th IEEE Asilomar Conf. on Signals, Systems and Computers, a textbook (Immersive Audio Signal Processing from Springer-Verlag) as well as numerous products from licensees that won the best of CES awards in various categories over the years.

How do you picture the future of sound quality?

Object-based audio and the ability to pinpoint objects in 3D space (cinemas, homes, headphones) are significant steps toward giving precise localization for discrete sound events while giving the benefit of envelopment on spatially and signal decorrelated content is the correct next step.

What's your latest project?

Some of the work I am involved in includes researching new techniques requiring deep-learning and AI for analysis of traditional 5.1 and object-based audio.

Why is your work important?

It helps advance the state-of-the-art audio/acoustical solutions, provide innovation and IP for HP, and most importantly, improve the quality of experience (QoE) on HP devices while saving dollars.

NOT JUST A WIND TUNNEL

HOW HURRICANES WORKS

SAFFIR – SIMPSON HURRICANE SCALE

Category	Wind speed km/h	Wind speed mph	Storm surge metres	Storm surge ft	Damage
01	119 – 154	74 – 95	1.2 – 1.5	4 – 5	Some flooding; little or no structural damage
02	155 – 178	96 – 110	1.8 – 2.4	6 – 8	Coastal roads flooded; trees down; roof damage (shingles ripped off)
03	155 – 178	96 – 110	2.7 – 3.7	9 – 12	Severe flooding; structural damage in houses and mobile homes destroyed
04	211 – 250	131 – 155	3.9 – 5.5	13 – 18	Severe flooding inland; some roofs ripped off; major structural damage
05	> 250	> 155	> 5.5	> 18	Severe flooding farther inland; serious damage to most wooden structures

Source: science.howstuffworks.com

> "IT'S NOT GOING TO BE JUST A WIND TUNNEL, BUT THE BEST WIND TUNNEL IN THE WORLD."
>
> PETER HAUGE MADSEN, HEAD OF DEPARTMENT AT DTU WIND ENERGY

Named after a Danish scientist and passionate inventor recognized for his early work on wind power, the Poul La Cour wind tunnel at DTU Risø Campus, Roskilde Denmark, is among the biggest university-owned wind tunnels in the world. Its size, the high air flow rates and the fact that it is possible to combine aerodynamic and aeroacoustic measurements all contribute to its uniqueness. Inaugurated in April 2018, the DKK 85 million, state-of-the art wind tunnel gives not only Danish researchers but also researchers and R&D engineers from all over the world, access to high-tech facilities and data and reinforces DTU's and Denmark's position as world leaders and pioneers within the field of wind energy.

DOUBLE ROOM

Objects under test – ranging from parts of wind turbine blades to downscaled models of turbines, towers, vehicles, buildings, etc. – are mounted in the 3 × 2 m test section, which has two configurations for the walls: the hard wall configuration for aerodynamic measurements, and the Kevlar® wall configuration for aeroacoustic measurements. The test section is also surrounded by an anechoic chamber to avoid reflections and to absorb noise. An important feature of the wind tunnel is the low background noise obtained by strategically positioned components to absorb noise from, for example, the big electrically driven fan.

HURRICANE FORCE

Powered by a 2.4 MW motor, a 4.7 m diameter fan exposes the test models to wind speeds of up to 105 m/s or 378 km/h.

The aerodynamic noise from, for example, wing sections in the test section is measured by Bruel & Kjær's 2 m diameter, sliced wheel array with 84 microphones placed in the anechoic chamber outside the air flow

These high wind speeds replicate the speeds at which wind turbine blades move. Hurricane Wilma, the most intense hurricane recorded by the US's National Hurricane Center, only reached wind speeds of 296 km/h. To determine the forces to which the model is exposed, the surface pressure is measured both on the test model itself and on the walls of the test section. The noise is measured by Brüel & Kjær's 2 m diameter sliced wheel array with 84 microphones placed in the anechoic chamber outside the air flow.

This unique wind tunnel will serve both research institutions and global industries, but with emphasis on tests for wind energy purposes.

MEASUREMENT MICROPHONES EXPLAINED

Microphones are present in almost all our electronic devices – from mobile phones, PCs and portable speakers, to TV, tablets and smart watches. In this article, we walk you through the physics of microphones that are specifically designed to be used in systems that quantify sound: measurement microphones.

Brüel & Kjær has developed and produced high-end measurement microphones since 1945. We have uninterruptedly worked on research and development and on calibration methodology to ensure continuous improvements in microphone accuracy and performance. Today, this approach contributes to a wide portfolio of measurement microphones covering all kinds of applications from acoustic seismic detection systems to airbag measurement and ultra-sonic applications.

PHYSICS

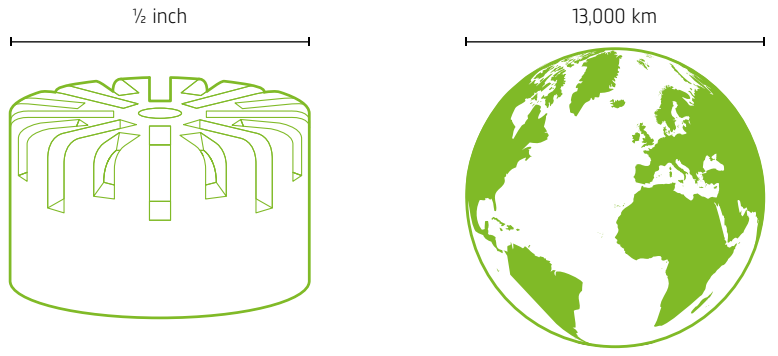
Measurement microphones are based on a very simple physical principle: capacitance. The capacity of a microphone is inversely proportional to the distance between the backplate (a stiff plate), and the diaphragm (a thin, highly tensioned metal foil). When exposed to sound pressure, the diaphragm deforms and moves closer to or further away from the backplate, changing the capacity of the system.

These variations in capacitance are converted to voltage variation. Most measurement microphones are based on this principle.

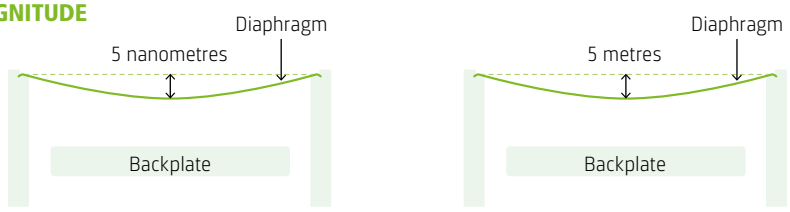
SIZE

Measurement microphones come in diameters of 1-, ½-, ¼- and ⅛-inch. The bigger the diaphragm, the less stiff it is and better to detect smaller sound pressure variations. On the other hand, the size of the diaphragm limits detecting frequencies with wavelengths that are in the same range or bigger than the diaphragm. Large diaphragms give lower noise, while small diaphragms allow high frequency. Small-sized microphones allow better omnidirectional characteristics at high frequencies. ▶

DIAMETER



MAGNITUDE



The displacement of the diaphragm for a typical ½-inch microphone is only in the magnitude order of 5 nanometres for an excitation of one pascal. For comparison, a diaphragm with a diameter the size of planet earth, would barely move 5 metres

The wavelength of a 20 kHz sound wave (the upper limit of the audio range) is 1.7 cm. That is approximately the width of the index finger

BY: **DR RÉMI GUASTAVINO**
Domain Specialist, Acoustics
Brüel & Kjær

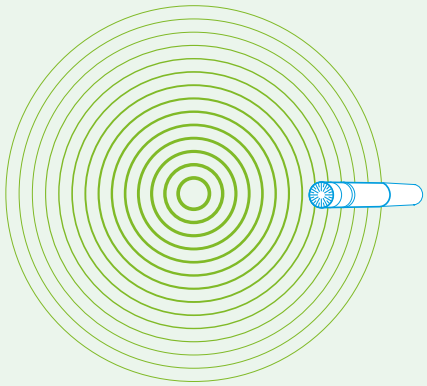
SOUND FIELD EXPLAINED

Measurement microphones, by their size and shape, influence the sound pressure. This influence, which depends on the type of sound field, is considered in each microphone's design and the microphone responses are optimized to compensate for the influence. This allows us to always give a flat response for the chosen sound field. Measurement microphones are divided in three main types, each type optimized for one of the three main types of sounds field, and it is important to choose the microphone that is best suited for the sound field.

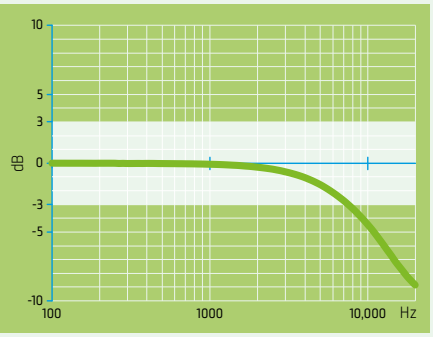
FREE-FIELD

A free-field is a sound field where sound waves can propagate freely without any disturbing objects. This means a space with no reflections. Sound fields with a close resemblance to free-field can be achieved in an anechoic chamber or emulated using a time-selective response (TSR) algorithm.

Free-field microphones are typically used to measure, for example, loudspeakers or outdoor sound.



DID YOU KNOW?
Using a free-field microphone in a pressure-field environment gives an error close to 9 dB around 20 kHz.



DIFFUSE-FIELD

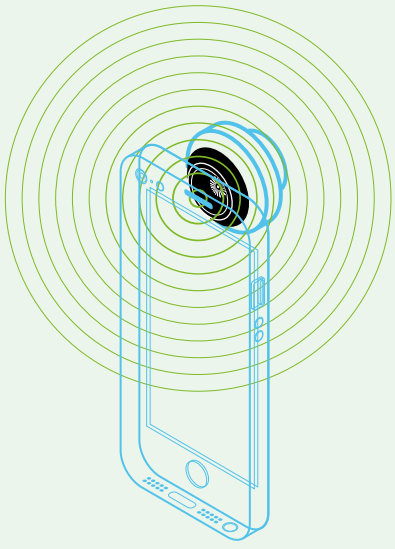
A diffuse-field is created by sound waves arriving simultaneously from all directions with equal probability and level. Sound fields with a close resemblance to diffuse-field can be achieved in environments such as buildings with hard walls, where many simultaneous sound or noise sources exist; in-cabin measurements and churches. If you are not sure about the sound field you are in, it is best to assume that it is diffuse to minimize measurement error.

Diffuse-field microphones are typically used to measure vehicle interior noise or building acoustics.

PRESSURE-FIELD

A pressure-field is sound pressure that has the same magnitude and phase at any position within the field. Sound fields with a close resemblance to pressure field can be achieved in small cavities (small compared to the wavelength) such as artificial ears.

Pressure-field microphones are typically used in couplers, wind tunnels or in any flush-mounted measurement.



MEASUREMENT
MICROPHONES EXPLAINED

DID YOU KNOW?
Laboratory Standard Microphone Types 4180 and 4160 are so extremely stable that all absolute acoustical measurements worldwide are relative to their reference sensitivity. There are no direct sound pressure sources that can produce the pascal with sufficiently low uncertainty over a wide frequency range.

SENSITIVITY

The sensitivity is the voltage produced by microphones under a defined sound pressure. It is defined in V/Pa and is frequency dependent.

A sound pressure of one pascal corresponds to a level of 94 dB SPL. That is why most microphone calibrators (for example, Brüel & Kjær's Sound Calibrator Type 4231) produce 94 dB SPL or 1 Pa.

FREQUENCY RESPONSE

Because sensitivity is frequency dependent, the frequency response is defined as an expression of the sensitivity in the entire frequency range. This is generally expressed in decibels relative to the 250 Hz sensitivity.

DYNAMIC RANGE

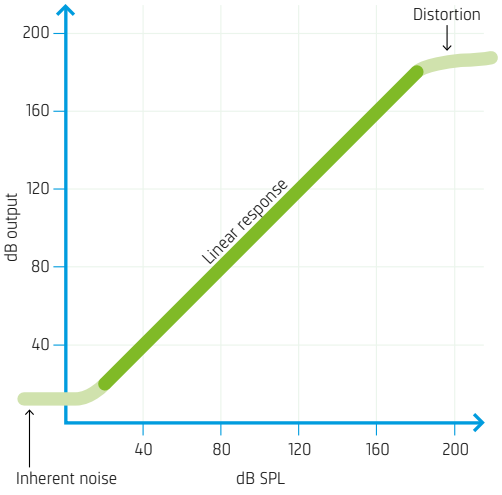
The dynamic range of measurement microphones (for example, 16 dBA – 143 dB) is the range where the microphone acts as a perfect linear transducer.

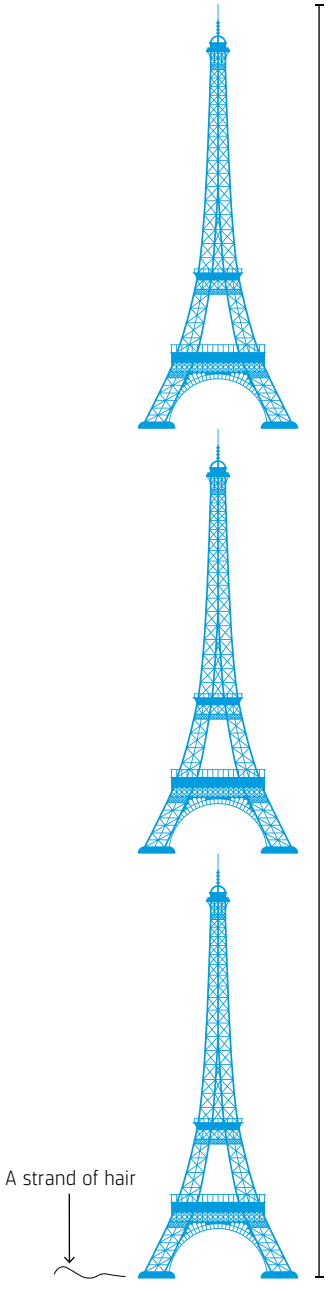
The first number is the inherent noise. Both condenser microphones and preamplifiers have an inherent noise caused, among other things, by limitations in the electronics and Brownian movements. This number indicates the sound pressure level that would create the same voltage as the noise generated by the microphone itself. The noise is historically measured in third-octave band, A-weighted in the human hearing range (between the 22.4 Hz and 22.4 kHz band), if nothing else is specified.

The second number is the highest sound pressure level measurable with less than 3% total harmonic distortion.

The dynamic range of a microphone is often limited by the preamplifier. For example, a CCLD (constant-current line drive) preamplifier is designed to deliver a maximum of 7 V peak for frequencies lower than 20 kHz. This gives a maximum of 134 dB SPL for a microphone sensitivity of 50 mV/Pa. It is possible in this case to extend the upper limit of the dynamic range to 146 dB by using a classical preamplifier.

A MICROPHONE'S DYNAMIC RANGE





Brüel & Kjær's ½-inch Free-field Microphone Type 4191 has a dynamic range of 20 dBA to 162 dB (this is 142 dB). If we convert this ratio to distance, the measurement would stretch from a strand of hair to more than three Eiffel Towers stacked on top of each other

SECURING STABILITY

Brüel & Kjær measurement microphones are designed to be extremely stable, especially over time, temperature, humidity and ambient pressure. To achieve maximum stability, we use carefully selected, high-quality material; we apply controlled heat treatment to artificially age and release any tension in the cartridge and we continuously test each microphone at every step of the production process.

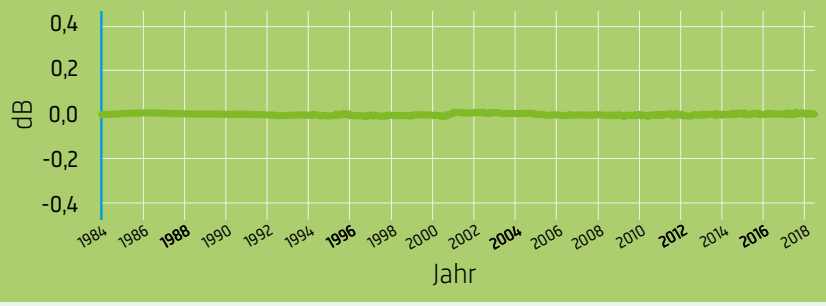
The microphones are exposed to multiple cleaning processes during fabrication in a class 10 clean room. In a class 10 clean room, there are less than 10 particles larger than 0.5 µm and less than 2 particles between 1 and 5 µm per cubic foot.

As a comparison, ordinary room air is approximately 'class 1 million'. Considering the distance between the backplate and the diaphragm being generally around 20 µm, any particles bigger than this that are present in the cavity would cause stability issues – especially when condensation or changes in temperature occur.

If the membrane is punctured, contamination will occur, and particles and residue will enter the cartridge. Achieving the same level of cleanliness during a repair may not guarantee a microphone with optimal response. This is the reason why Brüel & Kjær does not offer microphone repair.

DID YOU KNOW?

We have been carefully monitoring the sensitivity of our laboratory standard microphones Type 4160 and Type 4180 since 1984. The sensitivity stays in the ±0.02 dB range (this means less than 0.2% changes). These microphones are used all over the world in calibration systems.



SPOT THE DIFFERENCE

Can you spot the five differences between these two pictures?

See the solution on page 41.

MONICA TAKES ON TECHNO

The April issue of WAVES introduced the MONICA project, and its ambitious plan to help cities use the Internet of Things (IoT) to manage sound and security at large, open-air events. In July, MONICA made its real-world debut: at the Kappa FuturFestival in Torino, Italy.

ABOUT THE KAPPA FUTURFESTIVAL

- Electronic music festival held annually in Torino, Italy
- Four stages with concerts from noon to midnight
- Covers 450,000 m² and hosts 47,000 attendees from around the world

ABOUT THE MONICA PROJECT

- Three-year project co-funded by the European Commission
- Demonstrating how cities can use IoT technologies to manage sound and security at large, open-air cultural and sporting events
- 29 partners in nine countries

A view from the stage with apartment buildings in the background

Swirling spotlights cut a path across thousands of techno fans, their hands raised as they pay homage to deejay Joseph Capriati. One inexplicably waves a metre-long inflatable banana in front of the massive stage, and almost all are still sweaty, even as the clock nears midnight. For nearly 12 solid hours, a hefty bassline has throbbed across the festival grounds, bullying its way towards the nearby residences.

But this year the chest-pounding pulse has met its match: the MONICA project. Or, at least, the first demonstration of what MONICA will be capable of.

Like all city concert venues, the Kappa FuturFestival aims to create the right balance between an optimal outdoor concert sound and reduced noise in the surrounding environment. The MONICA project's sound solution is designed to enable more accurate monitoring and control, both for a quality concert experience inside the venue and to limit sound propagation outside the venue.

"You need high sound pressure levels for an optimal concert sound, which is, of course, what the audience and the performers want. But you might have to turn down the volume because of sound level regulations. And even when you comply with those regulations, the neighbours might still complain. It's tricky," says Brüel & Kjær Research Engineer Karim Haddad, PhD, who is actively involved in the MONICA project.

With the help of staff from the city of Torino, Karim installed Brüel & Kjær's specially designed sound level meters at the Kappa FuturFestival and actively monitored them throughout the event.

MEASURING SOUND LEVELS

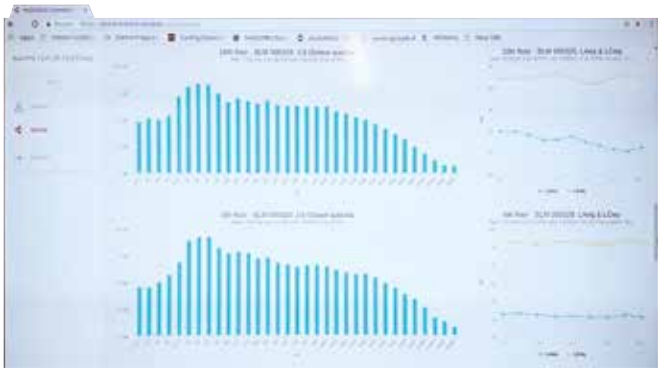
The sound level meters were used both within the concert area and outside the festival grounds. Each of the festival's four stages had a sound level meter situated roughly 20 m in front of the stage. Five additional sound level meters were placed in the most exposed private residences outside the festival grounds to monitor the music's impact on non-concertgoers nearby.

"We measured the noise levels and the spectra at each of the locations," explains Karim. "All the data was sent in real time to the cloud and used by technicians to make any necessary adjustments. If the level was above the acceptable guidelines for the city, then they reduced the level on the loudspeaker system inside the park area." ▶

MONICA
TAKES ON TECHNO

Five sound level meters were placed in the most exposed private residences outside the festival grounds to monitor the music's impact on non-concertgoers nearby

Overview of the time-updated acoustic levels and spectra via the Web-based MONICA common operational picture (COP)



SOUND FIELD CONTROL SYSTEM ADAPTS AS NEEDED

The Technical University of Denmark (DTU), also a partner in the MONICA project, plays a key role in the sound solution. While Brüel & Kjær is responsible for detecting, measuring and analysing the sound data, the university's task is to optimize and predict sound transmission. In Torino, DTU set up 16 loudspeakers (subwoofers) behind the audience area at the "Futur" stage. The subwoofers are ideal for reproducing low-pitched audio frequencies. Five rows of 10 Brüel & Kjær microphones were placed approximately 50 to 150 m behind the subwoofers in the dark zone, which is an area where lower sound exposure from the stage is desired.

"The basic idea of the adaptive sound field control system (ASFCS) is using the secondary set of subwoofers to produce a sound field that is the same as the one produced by the original PA system subwoofers, but with opposite phase, and thus opposite sign. When adding the two, the result should be close to zero," explains Jonas Brunskog, PhD, Associate Professor of Acoustic Technology in the DTU Department of Electrical Engineering.

"The microphones are used to measure transfer functions between all loudspeakers and microphones, before the concert. These are then used to find filter functions for each of the 16 added loudspeakers, found so that they minimize the sound pressure level in the dark zone where the microphones are located."

"Background noise from traffic and the other festival stages made for problematic conditions, which affected both the quality of the measurements and the qualitative experience of the system," Jonas says. However, the test was considered successful, since they achieved a reduction of about 6 dB at low frequencies.

A SUCCESSFUL START

The city of Torino, one of six pilot sites for the MONICA project, believes the demonstration of the sound system bodes well for its sister sites and, eventually, widespread use.

"The city of Torino deeply relies on continuous noise monitoring for the control of outdoor events, and the MONICA project successfully strengthened this approach. For this reason, we supported project demonstration at our best with local police, green areas staff and topographers," says engineer Enrico Gallo, who works for the Municipality of Torino in its Environment, Green Areas and Civil Protection Division.

> "ALL THE DATA WAS SENT IN REAL TIME TO THE CLOUD AND USED BY TECHNICIANS TO MAKE ANY NECESSARY ADJUSTMENTS."
>
> KARIM HADDAD
> RESEARCH ENGINEER, PHD, BRÜEL & KJÆR

In addition to collecting and using the measurements in real time, the city of Torino analysed all the sound data collected throughout the festival to determine how much each stage contributed to the overall sound levels at the locations measured.

"The chance of having detailed, real-time data from each stage and at dwellings together with ASFCS really opens new opportunities for noise and annoyance reduction," Enrico says.

NEXT UP

Karim, from Brüel & Kjær, shares Enrico's enthusiasm. "We got what we wanted! The results were what we expected, so now we can move on with our plan."

For Brüel & Kjær, next steps include adding time data to the cloud, so that it's possible to listen to the actual sounds recorded and to implement its algorithm for distinguishing concert noise from city noise and add it to the cloud.

"We're in the second year of the three-year project," Karim explains. "Next year we'll have to demonstrate the system fully working at lots of different festivals."

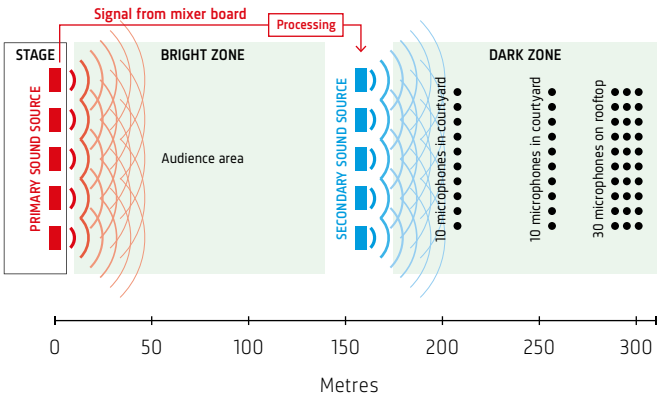
In his opinion, the MONICA project's dependency on the cloud is its biggest challenge.

"We're depending on the network, which can go down when there are so many people using it, and which can be vulnerable. It went well in Torino, but it depends on the local network. You have to be sure it's reliable," Karim cautions.

And having 29 different MONICA partners collaborating on different aspects of the same mammoth undertaking brings its own set of challenges.

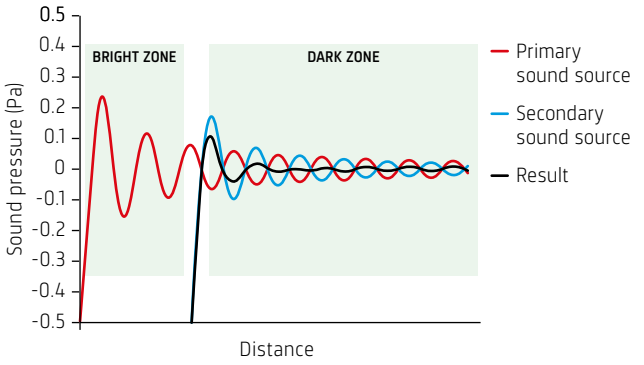
"What's interesting about a project like this is that you interact with people from different companies, universities and institutions who are not working in your field. You have to adapt your language, and they have to adapt their language, because of different expertise domains. And even working within Europe, you have different cultures. But if people have the good will, then it works well. And every partner on this project works seriously."

ADAPTIVE SOUND FIELD CONTROL SYSTEM



The 5 x 10 microphones in the dark zone are used before the concert to estimate the transfer function between the two sets of sound sources and each microphone in the dark zone. During the concert, the signal from the mixer board is processed using the measured transfer function

ACTIVE SOUND CANCELLATION



When the MONICA sound system mixes the sound from the concert with 'anti-noise' from the secondary speakers, the sound waves even out resulting in less noise in the dark zone


The Green Man
The perfect listener, aka High-frequency Head and Torso Simulator Type 5128, aka The Green Man from Brüel & Kjær
www.bksv.com/high-frequency-HATS


Brüel & Kjær

MANAGING STEALTH WITH A SELF-NOISE MONITORING SYSTEM

T26 GLOBAL COMBAT SHIP

Top speed:	26+ knots
Range:	Excess of 7,000 nautical miles in Electric-Motor (EM) drive
Accommodates:	208 crew and 157 core complement
Main dimensions:	Displacement: 6,900 tonnes Length: 149.9 metres Maximum beam: 20.8 metres
Entering service:	In the mid 2020s

As a world-class naval engineering business, BAE Systems has been working with the UK Ministry of Defence (MOD) to design a new class of frigate: the Type 26 Frigate. To ensure the acoustic stealth of this new class of combat ship, BAE Systems needed a world-class self-noise monitoring system.

WORLD-CLASS NAVAL ENGINEERING

BAE Systems is a global defence, aerospace, and security company employing people in over 40 countries and working closely with skilled partners. Providing a competitive edge in the air, at sea, and on land, as well as in the cyber world, BAE Systems designs, manufactures, and supports complex surface ships, submarines, torpedoes, radars, and command and combat systems.

Designed to protect powerful new aircraft carriers, the Type 26 Frigate is a cutting-edge warship that will replace the UK's Type 23 Anti-Submarine Warfare (ASW) Frigates. Designed for a service life of at least 25 years, eight Type 26 Frigates will form the backbone of the Royal Navy surface fleet well into the 2060s.

MANAGING A SHIP'S ACOUSTIC SIGNATURE

When life at sea in hostile conditions depends on not being detected, the importance of acoustic stealth cannot be underestimated. Because of its ASW role, where the T26 Frigate must protect the fleet against potential intruding submarines, it is very important that the ship is quiet and that the crew is able to monitor exactly how much noise and vibration is being generated. The acoustic signature – the noise and vibration a vessel and its on-board equipment and systems make in the water – is a key requirement for such vessels and it must be kept as low as possible in order to avoid detection.

ESSENTIAL MONITORING

To maintain acoustic discretion, all noise sources of a vessel are taken into consideration, including personnel, on-board equipment and cavitation, as well as the radiated noise signature of the vessel as a whole. Reducing a ship's radiated noise signature is a key element to its tactical deployment, and a self-noise monitoring system is essential to manage the ship's acoustic signature.

BAE Systems takes acoustic stealth very seriously and following the success of several earlier projects have again selected Brüel & Kjær to deliver a commercial off-the-shelf (COTS) self-noise monitoring system (SNMS), also known as hull vibration monitoring equipment (HVME), for the first three Type 26 Frigates.

Chris Curtis, Type 26 Supply Chain Director said, "Brüel & Kjær's previous record of delivering high-quality products to BAE Systems on previous programmes supported the contract award for the HVME. On the Type 26 Frigate, our suppliers are integral to the success of the programme, which is why it is important to have a trusted relationship where we can work together to deliver."

COMPLETE SENSOR NETWORK

Based on the PULSE™ scalable platform, the self-noise monitoring system is made up of a network of COTS equipment and includes sensors, data acquisition and vibration measurement and analysis capabilities. ▶

> "ACOUSTIC DETECTION AND IDENTIFICATION TECHNIQUES CONTINUOUSLY BECOME MORE ADVANCED AND SOPHISTICATED, AND WE HAVE TO ENSURE THAT WE GET THE RIGHT CUTTING-EDGE SOLUTION THAT MATCHES THE RIGOROUS REQUIREMENTS OF THE T26."
>
> ANDY KELLETT,
> THE UK MOD'S REQUIREMENTS MANAGER FOR THE T26

MANAGING STEALTH WITH A SELF-NOISE MONITORING SYSTEM

The acoustic signature is managed by monitoring structure-borne vibration and reviewing the vibro-acoustic information. This helps ship staff to control noise sources coming from machinery, hydrodynamic flow and propeller cavitation.

The system provides an instant overview of the radiated sound of the ship via permanently installed sensor arrays mounted internally on the ship's structure, and the continuous vibration monitoring of the ship's hull helps the crew to maintain a low noise signature.

MODULAR SOLUTION THAT FITS (ALMOST) ANYWHERE

The system offers some huge benefits: when space on a warship is at a premium, the practically zero footprint of the solution is an important factor. The data acquisition units can be hidden in small spaces, and the network architecture provides installation flexibility and radically reduces the amount of sensor cabling throughout the ship, which in turn provides a valuable cost and weight reduction. BAE Systems also appreciate that the off-the-shelf system is a complete, integrated solution – it includes all the necessary sensors, data acquisition units and software, covering the whole measurement chain. COTS solutions are advantageous because they ensure customers avoid outdated technology, which in the naval engineering world is not only inefficient but can dangerously lead to the inability to carry out prescribed operations.

> "ACOUSTIC STEALTH IS OF PRIME IMPORTANCE FOR THE OPERATIONAL SUCCESS OF THE T26."
>
> ANDY KELLETT,
> THE UK MOD'S REQUIREMENTS MANAGER FOR THE T26

In addition, Brüel & Kjær's partnership and its ability to manage this programme over the entire lifetime of the ship, which is at least 25 years, were important selection criteria for this project. The system is an integrated part of T26 Frigate, and the long-term commitment includes responsibility for integrated logic support, including the provision of spares and support.

ALWAYS UP-TO-DATE

The self-noise monitoring system for the first three T26 Frigates ensures that BAE Systems gets a commercially mature technology with an open architecture. And it means that BAE Systems is always up-to-date with hardware and software and that the ships have a cutting-edge, acoustic-stealth solution well into the long-term future. ■

HYDROPHONES

The 'hydro' in hydrophone is easy to spot. They have been designed for use in water, but those features that make them particularly useful in aquatic environments can also translate to the gaseous environment.

Aquatic environments, particularly salt-water environments, introduce a variety of conditions that require special measurement considerations. Water incurs much less damping than air, so hydrophones must be able to withstand high sound pressure levels before distortion. The size of the sensor is less of an issue. Because wavelength is the speed of sound divided by frequency and sound travels much faster through water, the waterborne frequency will have a longer wavelength than in air, so the sensing element can be larger. Hydrophones, depending on model, can function at depths of 1000 m and withstand static pressures of up to 100 bar. The exterior is also corrosion resistant to withstand high salinity, etc.

A HYDROPHONE OUT OF WATER

The elements that make these hydrophones great in the aquatic environment also translate to making them great microphones in non-aquatic environments, particularly extreme and harsh ones, like a launchpad or jet engine test stand. This comes into play in a couple of ways. The lower sensitivity of hydrophones means that they can provide good, clean and undistorted data even with very high sound pressure levels generated by the item under test.

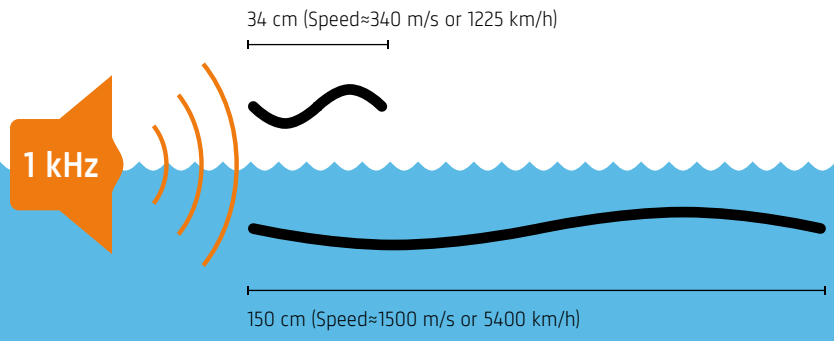
The other facet is durability unmatched by traditional atmospheric microphones. The hydrophone's ability to survive unattended in unhospitable environments means that it can be placed and forgotten.

SEE MORE
The physics of measurement microphones are explained on pages 18 – 21

SEE MORE
Turn the page and learn how JAXA uses hydrophones on their launchpad

WAVELENGTH
IN AIR AND IN WATER FOR A 1 kHz TONE

The wavelength is the spatial period of a periodic wave (the distance over which the wave's shape repeats)



TO SAFEGUARD THE PAYLOAD – REDESIGN THE LAUNCHPAD

In 2003, the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL) and the National Space Development Agency of Japan (NASDA) merged to become the Japan Aerospace Exploration Agency (JAXA). JAXA, as of 2015, is part of Japan's National Research and Development Agency, supporting the government's overall goal to use space for the betterment of society.

The 2018 launch of Epsilon-3 was more than the successful delivery of the payload to sun-synchronous orbit (SSO). This launch was a culmination of the efforts made to redesign the launchpad and thereby reduce the stress placed on the payload.

It is no surprise to anyone that getting a payload into orbit is an expensive affair, and not just for the launch itself. The payload, more often than not, represents millions of dollars of design, components, testing and man-hours. So, after all that expense, it is supremely important to take every precaution necessary to ensure that the investment makes it to orbit successfully. The most publicized method is stress testing the payload itself to ensure that it can survive the stresses of launch unscathed. But what if the overall stresses of the launch could be reduced?

With the introduction of their new Epsilon launch vehicle in 2013, JAXA targeted one of the contributors to the overall vibration. There are myriad contribution paths in any given structure, and the more complicated the structure, the greater the number of paths. Some paths are more apparent than others, and some are more or less malleable than others. A special acoustic team requested by Epsilon rocket project was formed in JAXA to tackle the potential acoustic problems. In that team, an acoustic measurement team, led by Tatsuya Ishii, joined forces with Yutaka Ishii and Hiroshi Komatsuzaki of Brüel & Kjær to focus on an area that wouldn't be immediately obvious to the uninitiated: acoustically transmitted vibration from the rocket motor bouncing back up from the launchpad to affect the payload. ▶

Tatsuya Ishii received his PhD in mechanical engineering from the University of Tokyo and began his career at NAL in 1994, merging with JAXA in 2003. He is now a manager of engine acoustics in the Propulsion Research Unit of the Aeronautical Technology Directorate. Tatsuya is currently engaged in acoustic studies regarding aircraft engine noise, particularly jet noise reduction, active noise control, sound source localization, acoustic absorption and launch vehicle acoustics. ■

Standing in front of the JAXA launchpad area are (left to right) Research and Development Directorate Dr Seiji Tsutsumi, JAXA, Space Technology Directorate 1 Dr Kyoichi Ui, JAXA, Account Manager Hiroshi Komatsuzaki, Brüel & Kjær, Manager for Engine Acoustics of Aeronautical Technology Division Dr Tatsuya Ishii, JAXA and Application Engineer Yutaka Ishii, Brüel & Kjær

TO SAFEGUARD THE PAYLOAD – REDESIGN THE LAUNCHPAD

Epsilon-1 launch vehicle preparing for launch on the new launchpad

Airborne vibration actually contributes a surprising amount. During lift-off, the plume coming from the base of the rocket is not just the cloud of fire and smoke that spectators see from a distance, it is a very high-speed exhaust plume containing powerful shockwaves that radiate high levels of sound power that reflect from the surrounding environment, like the launchpad. The combined acoustic effects of this extremely harsh environment can potentially damage the payload.

In preparation for this project, computational and experimental projects were undertaken to understand the components and sound contributors and validate the acoustic environment around the vehicle. The results of these two preliminary projects indicated that the launchpad itself needed a major overhaul.

In order to mitigate this contribution path, JAXA began the process of redesigning the launchpad to deflect the extreme sound pressure away from the payload. To do this, they would need to find the optimal design that would most effectively protect the rocket and its payload from the plume and its contained shock-wave noise source. Through designing with numerical models, CFD finally proposed a couple of optimal entire launchpad models. Obviously, constructing multiple full-scale launchpads and performing multiple full-scale launches in order to test the possible designs would be prohibitively expensive.

Epsilon launch vehicles are solid-propellant, three-stage motor systems designed to transport a payload of up to 1.2 tons to LEO

Type 8103 hydrophone located on the sidewall of the launcher before and after launch

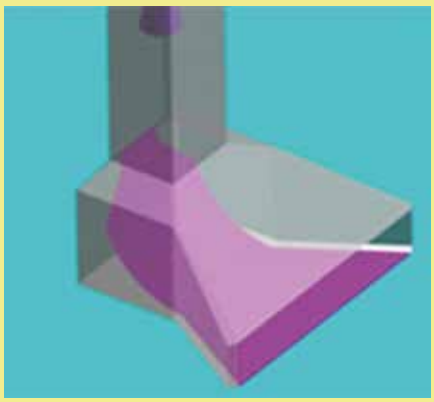
To determine the performance of the models including the shape of the exhaust duct, the JAXA team elected to employ beamforming due to its well-established capabilities for noise source identification. Beamforming provides an angular resolution of the contributions to the sound pressure measured at the array.

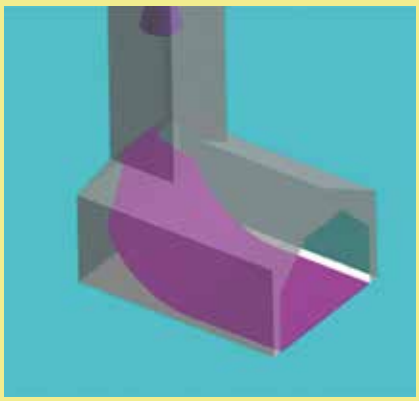
SCALED FOR CONVENIENCE

The local conditions around the scale model are not as extreme as around the full-scale system, so the equipment used would not need to meet the harsher requirements of the real environment. An added benefit of a scaled-down model is that the pertinent frequencies are scaled up, which means that sufficient resolution can be achieved with a much smaller and more manageable array than the full-scale system. ▶

M-V launch vehicle preparing for launch on the old launchpad

Computer models
of prospective exhaust ducts





TO SAFEGUARD THE PAYLOAD – REDESIGN THE LAUNCHPAD

Scale-model test setup

The small-scale beamforming system consists of a Brüel & Kjær optimized irregular 2.5-metre diameter, nine-arm array, a front-end system and software for data acquisition and for beamforming calculations

TYPE-1

TYPE-2

63 Hz 125 Hz 250 Hz

Noise source identification overlay of scale-model test

Array geometry is a key factor in obtaining good results from a beamforming system. A good array geometry is characterized by having a low maximum sidelobe level (MSL). For a measurement on a single small source, MSL is the difference in decibels between the true noise source and the strongest ghost source in the beamformed map. However, since the ghost source pattern is known (defined by the array geometry), it can be computationally removed by a so-called deconvolution algorithm.

To determine the contributions to the sound pressure at the payload, the array should ideally be placed at the payload and focused towards the dominant noise source (in other words, the plume). However, because of the interference of the support structure around the model and the need to avoid the fire of the rocket, the array was offset and placed at the minimum angle possible from the vertical direction.

The scaled measurements and the resulting data were analysed, and based on the results, the final launchpad design was chosen. The next phase was construction and then application of the full-scale system and testing to confirm correlation between the small-scale and full-scale systems.

TACKLING THE GIANT

The full-scale measurement required additional mitigations. Due to the

SEE MORE
Read about hydrophones on page 31

Epsilon-3
during lift-off

extreme environment near the launchpad, the array would need to be placed 70 metres from the launchpad. This solved the temperature problem but presented additional issues. Because the very low frequencies were the primary interest and because of the distance from the launchpad, a very large array was required to provide any useful resolution.

Fortunately, the most important resolution of interest was only along the horizontal plane through the rocket nozzle and the deflector outlet, assuming that the two main sources radiate omnidirectionally, eliminating the need to locate the array near the payload. This meant that the task could be performed by a horizontal line array on the ground.

Two additional issues encountered in the full-scale measurement were flow noise, which comes from the rocket motor exhaust blowing air and debris in the direction of the array, and very high sound pressure levels. Both of these issues were resolved using a solution that might not sound immediately obvious: hydrophones. Measurements were made with two Brüel & Kjær Type 8103 hydrophones during the first Epsilon launch to confirm time data correlation to microphones. Due to the advantages they offer when measuring high sound pressure levels in air and their demonstrated ability to provide quality data, hydrophones were chosen for the array that would measure both the Epsilon-2 and Epsilon-3 launches.

The very high sound pressure levels were accommodated through the hydrophone's design – they can deal with extremely high sound pressure levels. And flow noise, which interferes with the measurement and corrupts data, is minimized due to the aerodynamic shape of hydrophones.

THE PAYLOADS ARE SAFER

Throughout the entire process, the JAXA team was focused on a singular target: make the payload safer. And through a proven process of identifying the problem, testing solutions and validating results, they succeeded. The data gathered during the small-scale tests that yielded their final launchpad design was validated and, in real-world application, proven to have substantially reduced the acoustic vibration, and thereby the overall vibration affecting the payload.

WHO SAID **WHAT?**

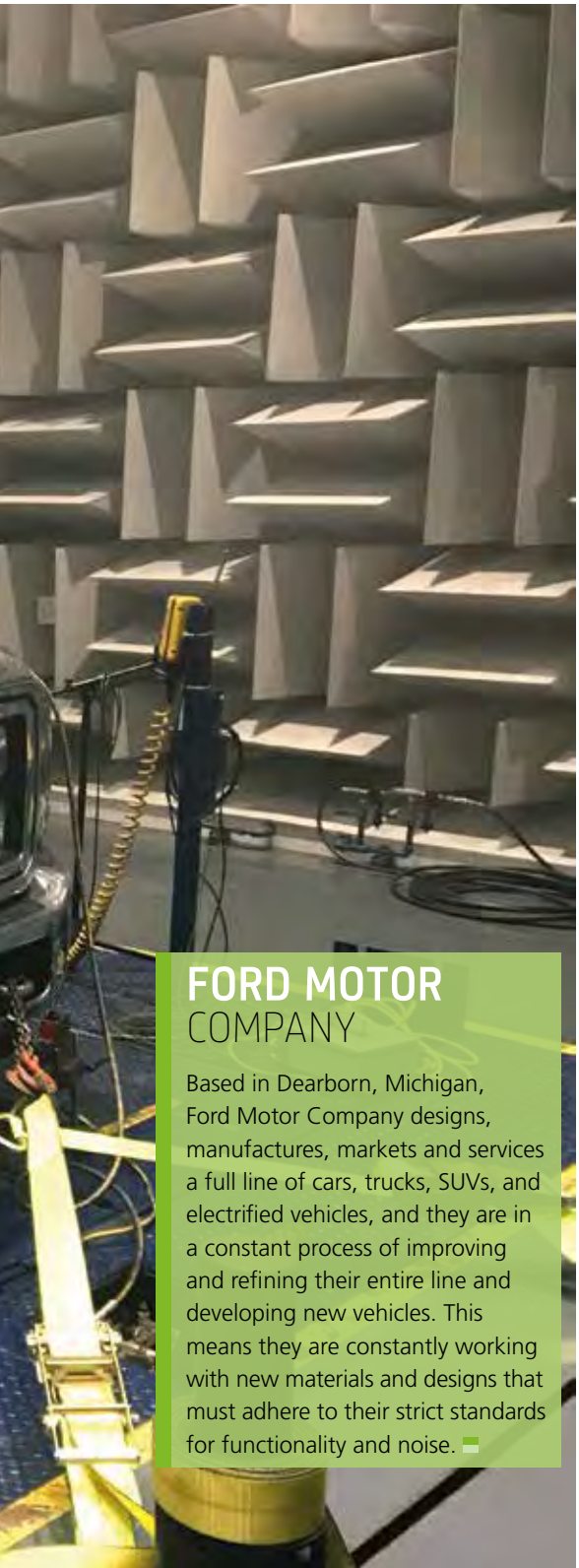
"IT IS IMPOSSIBLE FOR A MAN TO LEARN WHAT HE THINKS HE ALREADY KNOWS."

EPICTETUS
(55 – 135 AD)

Though born a slave, Greek Stoic philosopher Epictetus spent the last part of his life a free man and based his teaching on the works of the early Stoics. He believed that an individual is responsible for his own actions and that efforts spent trying to control external events are useless and a waste of energy. It is what it is.

STOP THE

NOISE



FORD MOTOR COMPANY

Based in Dearborn, Michigan, Ford Motor Company designs, manufactures, markets and services a full line of cars, trucks, SUVs, and electrified vehicles, and they are in a constant process of improving and refining their entire line and developing new vehicles. This means they are constantly working with new materials and designs that must adhere to their strict standards for functionality and noise.

Located in Canton, Michigan, Material Sciences Corporation (MSC) is a materials supplier and engineering services provider, primarily working on innovative solutions for lightweighting, acoustics and coated-metals solutions. They offer products and services for a wide range of industries and markets – from automotive to appliances.

A Ford GT, the sleek supercar successor to the 60s GT40 Le Mans champ, comes to a stop at a light, the driver and passers-by listen to the low, pleasantly menacing rumble of the engine. Not long after, a Ford Galaxy van pulls up next to the GT, and while waiting for the lights to change, the parents remind the kids, for the forty-second time, that if they don't settle down they will turn right around and go home. These two vehicles are at opposite ends of the vehicular spectrum, but they have more in common than just having four wheels. In both cases, while stopping for the light, all the sounds heard were exactly the sounds intended to be heard: the carefully engineered growl of the GT and the back-and-forth conversation of the parents and children. What they didn't hear was the equally well-engineered silence of the brakes. Brakes are a vital component in vehicles, but they are not something people want to notice. Brakes are just supposed to work, quietly and effectively: rain, sleet, snow, blazing heat or freezing cold – they must make the car stop without one tiny squeak.

MSC works with original equipment manufacturers (OEMs) like Ford to make sure that the materials used to make the brakes can meet the requirements of the target market group (be it the durability demanded by transport vans and family wagons or the stopping power required to reign in the mass of a heavy-duty work truck) without contributing one single decibel to the overall cabin noise. ▶

> "EVEN IF THE VEHICLE IS WORKING GREAT AND THE BRAKES ARE FUNCTIONING PERFECTLY, CUSTOMERS WILL TAKE A VEHICLE BACK TO THE DEALER WITH A POSSIBLE WARRANTY CLAIM IF THE BRAKES SQUEAL."
>
> CHARLES EVANS
> BRAKE TECHNICAL EXPERT, FORD MOTOR COMPANY

STOP THE NOISE

MSCs climate-controlled semi-anechoic test chamber can transform a comfortable room temperature into a humid –15 °C, then with a series of hard stops jack up the brake temperature to 300 °C – in under 24 hours

A MAJOR CHALLENGE

Motor vehicles are used privately and commercially in just about any environment imaginable, and the stresses placed on material components can differ drastically depending on the environmental conditions. Driving or, more to the point here, braking hard or gently at +45 to –45 °C with zero to 100% humidity affects the brake components in drastically different ways, and the components need to be tested across those environmental spectra.

Ford has been in the industry for a very long time. And because they keep track of the weather conditions and locations where brake noise issues have been reported, they have a good idea where potential problems can creep in. These locales are not the environmentally placid and stable climates, but places where temperature and humidity can reach extremes or change rapidly and drastically. They are also not environments that are readily available or convenient for testing outside, and they're difficult, if not near impossible for most test houses to simulate.

The MSC test facility is not one of those places. They test on a four-wheel chassis dynamometer in a climate-controlled (temperature and humidity) semi-anechoic

> "WE [FORD] LIKE MSC'S TESTING EXPERTISE; GOOD DATA IS A MUST. WHEN YOUR NOISE NEEDS TO EQUAL ZERO, EVERYTHING THAT STANDS OUT IN THE DATA WILL NEED TO BE ADDRESSED."
>
> CHARLES EVANS
> BRAKE TECHNICAL SPECIALIST, FORD MOTOR COMPANY

test environment that can – in under 24 hours – transform a comfortable room temperature into a humid –15 °C, then with a series of hard stops jack up the brake temperature to 300 °C. And those tests can last up to two days – running non-stop. In these extreme environments, the measurement equipment used must not just to be able to survive the environmental changes, but be able to continue to provide accurate, reliable data throughout the process. To meet their needs, MSC uses a combination of a LINK dynamometer with Brüel & Kjær's PULSE™ LabShop software and LAN-XI data acquisition module, simultaneously measuring all four wheels with five to six channels.

THE PROCESS

The sequence of events that make up the testing process is often the same, whether it is a new brake system or an existing one. The vehicle to test is secured on the chassis dynamometer, then it is cycled across a range of speeds and brake conditions all under the various environmental conditions specified by Ford engineers. Ford also provides prototype and real-world data that is needed for correlation with chamber and environment simulation.

From this point, it becomes an iterative process that requires close collaboration between MSC and Ford.

At any given time, MSC may have two to three vehicles in various stages of testing, running the gamut of its environmental and performance parameters. This cycle through extremes generates a mass of data that is then provided to Ford, who makes adjustments based on that data. The close working relationship is important because the vehicle might be back the next day with a new set of test parameters. And this cycle of exchange and test continues until that ideal quiet brake is achieved.

THE PRODUCT

In the end, everyone benefits when things work like they should. The end user enjoys coming safely to a nice quiet stop without ever having to think about what is going on between the brake pad and disc. And MSC and Ford benefit from the results of having satisfied their respective customers. The return on investment for accurate, quality data and the determination to maintain stringent testing standards is well worth the price. ■

> "MSC SUPPORTS FORD BRAKE-NOISE TESTING WITH A RANGE OF SOPHISTICATED EQUIPMENT DESIGNED TO DUPLICATE REAL-WORLD CONDITIONS. WE RECORD ALL THE BRAKE NOISE DATA THAT FORD REQUIRES AND FORD MAKES TARGETED CHANGES BASED ON THAT DATA."
>
> MATT MURPHY
> VP ENGINEERED SOLUTIONS, MATERIAL SCIENCES CORPORATION

SPOT THE DIFFERENCE

The LAN-XI Light on page 21 was modified in five places.

Did you get it right?

LAN-XI Light is a rugged, stand-alone, 4-channel data acquisition module that supports CCLD transducers – perfect for use in the lab or field. It can be used together with a battery module to create a portable, remote recorder and is ideally suited for use with BK Connect applets, specific tools for specific tasks.

SEE MORE

www.bksv.com/lan-xi-light

www.bksv.com/applets

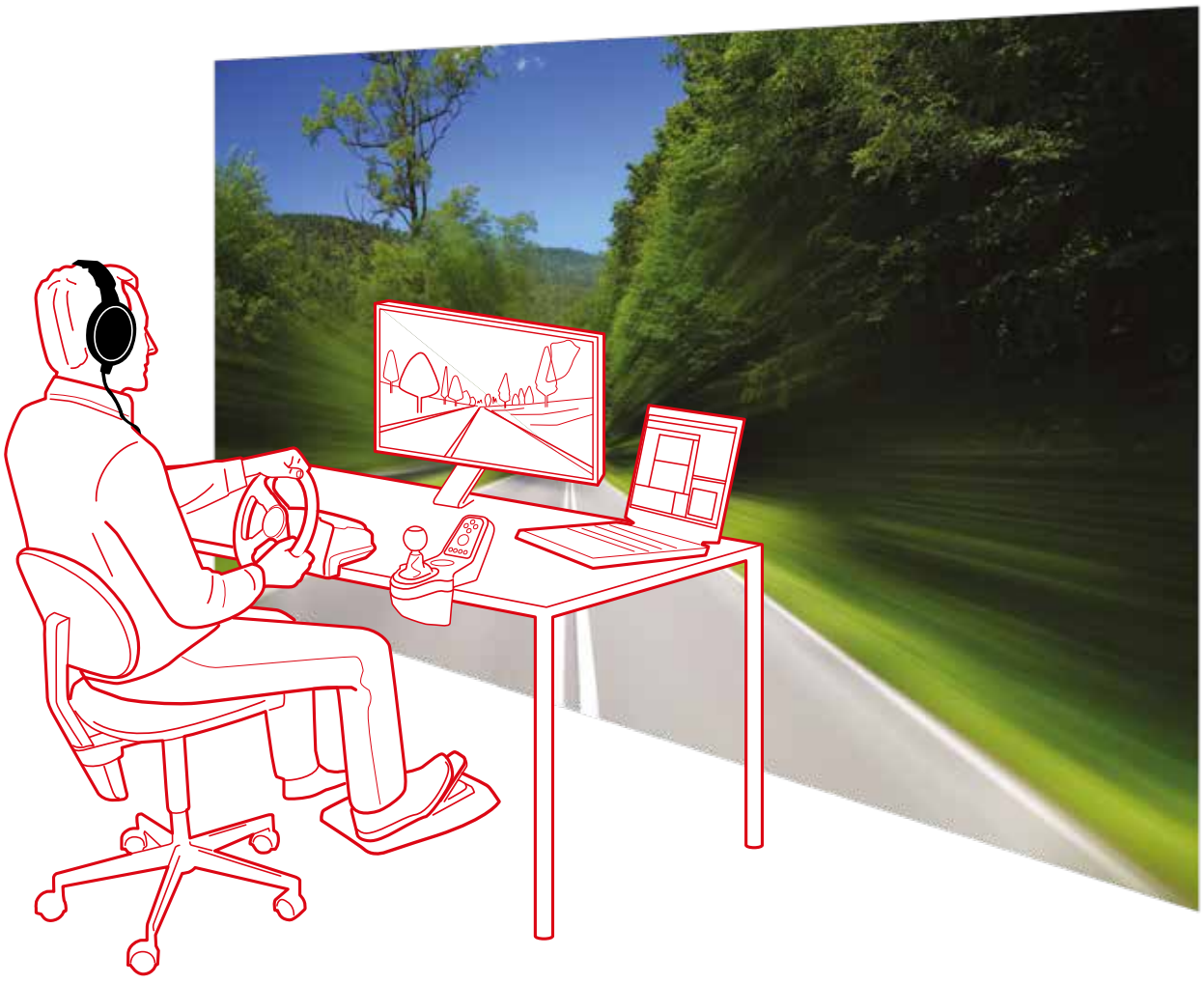
NVH SIMULATION AND CAE

Over time, product development has transitioned from paper-and-pen drafted designs to a computer-aided drafting (CAD) environment that allows earlier testing and faster, less costly redesign. The natural progression of this trend is for the digital phase to be integrated more fully into the design process with computer-aided engineering (CAE).

CAE enables the extension of the digital phase much further into the design process so that problems traditionally encountered in the prototype phase, and beyond, can be mitigated while still in a digital environment. Simply put, incorporating CAE can reduce cost and time to market.

WHAT IS CAE?

CAE is the incorporation of computer simulation to solve problems without the need to use a physical model or prototype, potentially eliminating the need for a prototype altogether. Testing technology can be applied during the design and development phases much earlier in the product life cycle.



In many sectors of the automotive and aerospace industries, CAE is being leveraged more and more. Companies strive to reach a stage of data accuracy and analysis where the simulations result in an initial prototype design that is, in fact, the product released for sale.

WHERE CAN IT BE USED?

CAE can bridge the gap between simulation data and real-world data and create synergy in any industry. The benefits of incorporating CAE become more pronounced in industries where the expense for design changes increase as they occur later in the production development process. The automotive and aerospace industries are prime examples, where the cost of new prototype production can be overwhelming.

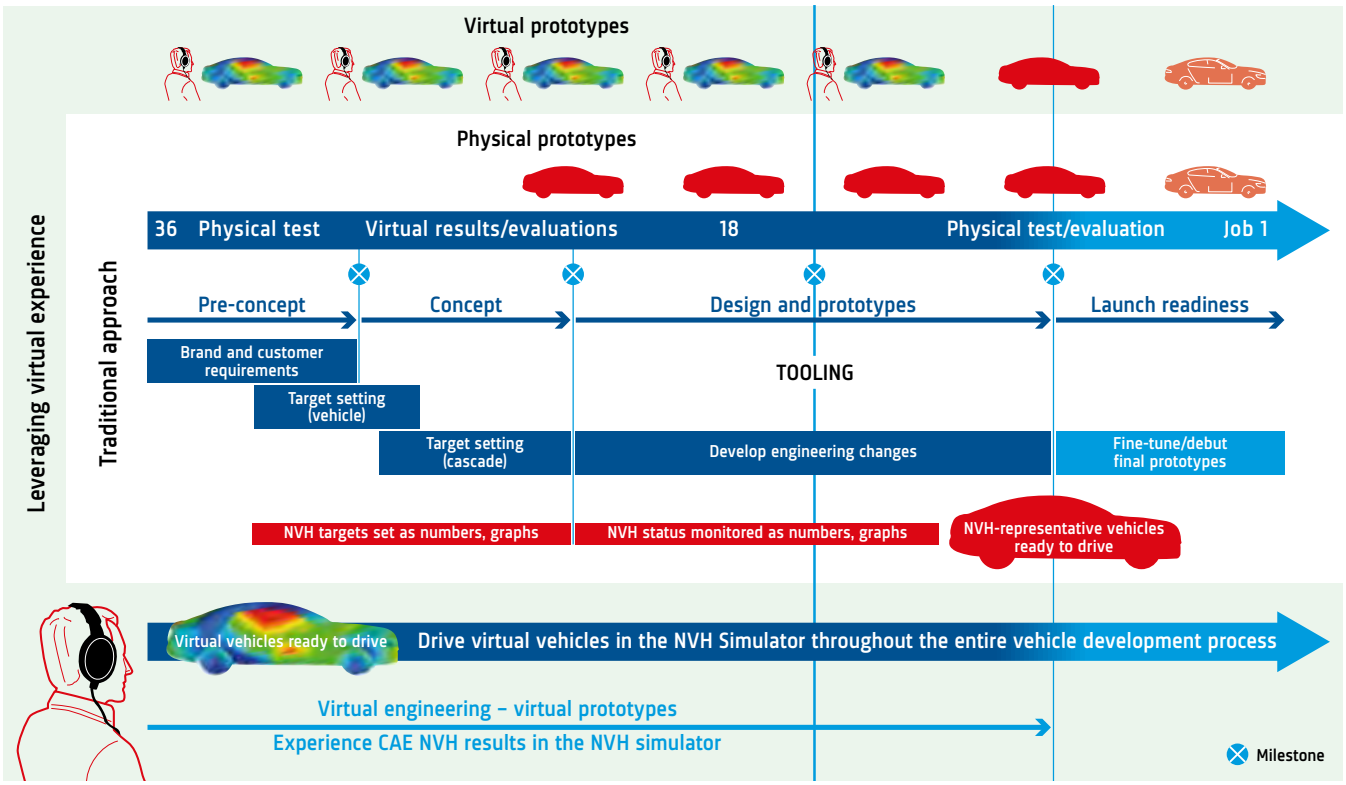
HOW DOES CAE BENEFIT THE TESTING WORLD?

The incorporation of CAE data into product development can offer engineers an opportunity to visually interact with the impacts to the design and quickly understand the effects of those changes. Two-dimensional NVH data cannot always be as easily understood as a 3D model of a finished product interacting with a simulated real world. By linking the power of simulation with the test results, data can be more effectively communicated and more informed decisions can be made earlier in the process.

CONCLUSION

There is a reason the phrase 'back to the drawing board' is dreaded. If the first tests are not performed until there are physical models and prototypes, there are any number of potential design quirks that could require new drawings, incurring a subsequent addition of cost in time and resources for new models or prototypes. By reducing the number of prototypes and by linking CAE into the process, overhead build costs can be reduced and decisions made quicker and earlier in the process, avoiding late development-stage fixes that can be extraordinarily costly.

VEHICLE DEVELOPMENT PROCESS



By leveraging CAE's simulation capabilities and virtual tools, engineers can shift the NVH decision-making to earlier in the process

NOWHERE

In 1984, we breathed a sigh of relief when we realized that we had not become the totalitarian state described in George Orwell's novel. There were no thought police, Big Brother wasn't watching us from giant screens and computing and surveillance technologies were still rudimentary.

Peeking from behind net curtains, or through a keyhole, listening to neighbours through a wall – such images smack of silent movies and murder mysteries. However, we are all guilty of eavesdropping. Curious by nature, we listen in on conversations in cafés, on public transport, in the office. We can't help ourselves, we like to know what's going on in people's lives, it's interesting, it's fascinating, and mostly harmless.

Historical and literary accounts of eavesdropping and espionage go back as far as ancient civilization, 6000 years ago. Egyptian hieroglyphics reveal the presence of court spies. The Trojan Horse,

TO HIDE

a tale of Ancient Greek subterfuge is described in length in Virgil's Aeneid. Rome's most famous case of espionage resulted in the assassination of Julius Caesar in 44 BC.

Eavesdropping in England during the Middle Ages was a punishable offence, not, according to records, to protect people's right to privacy, but because eavesdropping was "damaging to local harmony, goodwill, and peaceful relations between neighbours."[1] ▶

[1] Marjorie McIntosh Controlling Misbehaviour in England, 1370 – 1600

eavesdrop /ˈiːvzdrɒp/

Origin: Early 17th century: back formation from eavesdropper (late Middle English) 'a person who listens from under the eaves', from the obsolete noun eavesdrop 'the ground on to which water drips from the eaves', probably from Old Norse upsardropi, from ups 'eaves' + dropi 'a drop'.

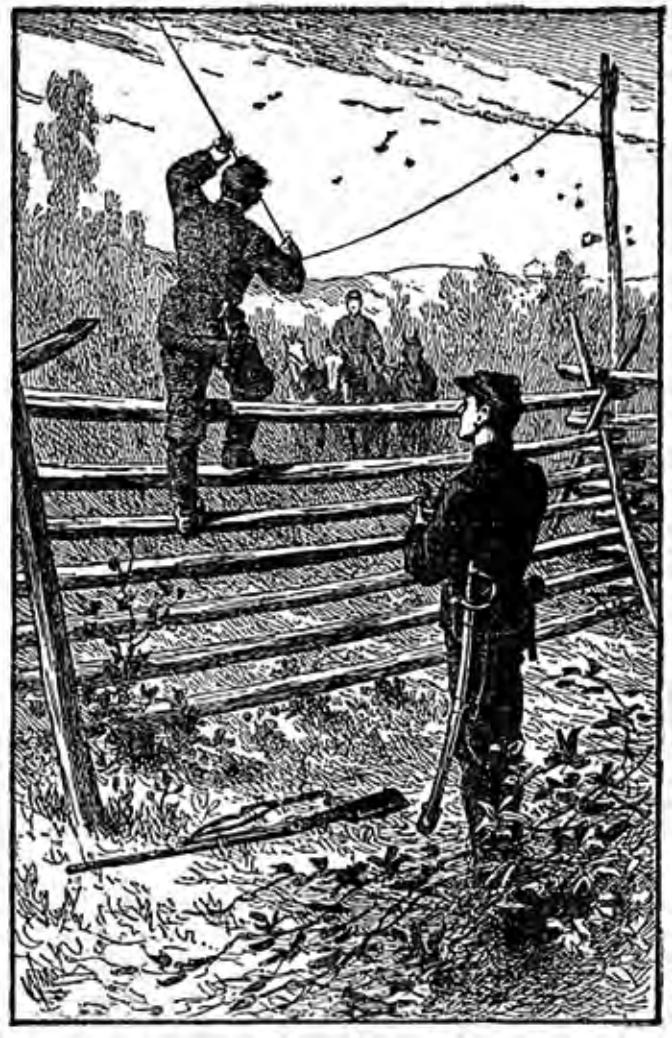
Source: Oxford Dictionary, Oxford University Press

NOWHERE **TO HIDE**

THE RISE OF DOMESTIC SURVEILLANCE

The origins of global surveillance can be traced to the late 1940s when the UK and US governments entered into the UKUSA Agreement, that culminated in the creation of a global surveillance network, code-named ECHELON. Created to monitor military and diplomatic communications of the Soviet Union and the Eastern Bloc during the Cold War of the 1960s, the system could, by the late 1990s, intercept satellite transmissions, PSTN communications, and even transmissions carried by microwave. ECHELON's existence was denied by both Britain and the US, but a report by the European Parliament in 2001 confirmed the programme's existence, warning Europeans that this was "a global system for the interception of private and commercial communications."[2] No longer a military or political act, surveillance was intruding into our private matters.

The telegraph revolutionized espionage operations. Using the dots and dashes of Samuel Morse's code, governments started sending messages over telegraph wires, and it wasn't long before rival intelligence services learnt how to listen to the messages by tapping the lines



Domestic surveillance escalated significantly in the 2000s. In Britain, 'an organized trade in confidential personal information'[3] had developed and was widely used by the British press. Unscrupulous and cynical journalists gathered information by every means possible from hacking private voicemail accounts and computers to entrapment, blackmail and theft of mobile phones.

The public's awareness of domestic surveillance heightened with the unravelling of the News International phone-hacking scandal involving News of the World and other newspapers published by News International, a subsidiary of News Corporation. Employees were accused of phone hacking, police bribery, and exercising improper influence in the pursuit of stories on celebrities, politicians, and members of the British Royal Family. However, the revelation that the phones of a murdered schoolgirl, the relatives of deceased British soldiers, and victims of the 7 July 2005 London bombings had also been hacked caused public outcry, leading to several high-profile resignations, including that of Rupert Murdoch as News Corporation director.

In 2013, computer programmer, and former subcontractor for the NSA, Edward Snowden, made headlines when he handed over 200,000 top secret documents to various media outlets, many of them detailing the monitoring of American citizens. The leaks reinforced the enormity of domestic surveillance proving that regardless of who you are, details of purchases you make by credit card, websites you visit, emails you send, hotels you book and events you attend are stored in some massive database somewhere to be searched through and assessed.

[2] Schmid, Gerhard (July 11, 2001) "On the existence of a global system for the interception of private and commercial communications (ECHELON interception system) (2001/2098(INI))"

[3] What Price Privacy, Information Commissioner's Office. 10 May 2006

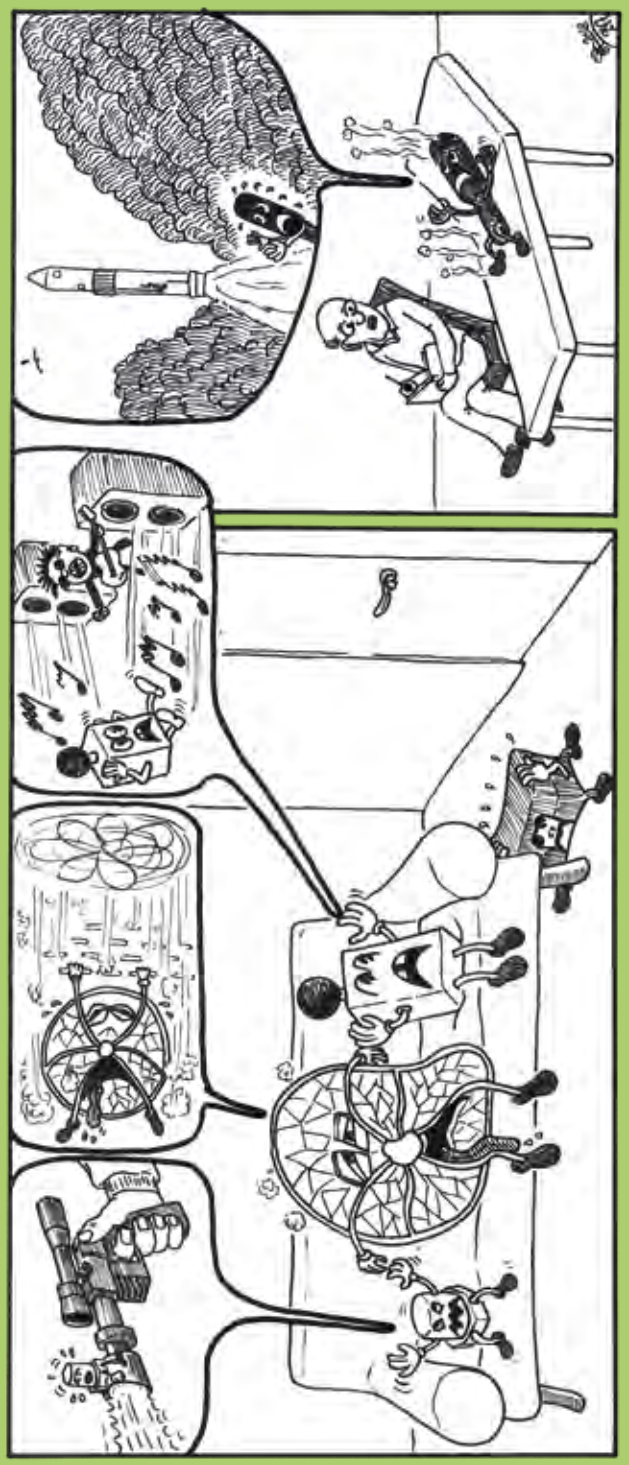
When Snowden's identity was revealed at his request, he said, "I do not want to live in a world where everything I do or say is recorded." And if we ignore the hero/traitor controversy that surrounds his person, who can disagree?

HACKED OFF

A customer concerned with mobile phone security contacted Brüel & Kjær for help in designing a device to prevent hackers from eavesdropping on conversations by misusing mobile phones.

The resulting box provides high attenuation of sound thanks to its optimized construction. To augment the sound attenuation, and ensure further enhanced security, random noise is produced inside the box once it is closed and activated. The noise is inaudible outside the box but masks even the loudest of conversations from the phones inside. Green indicator lights on the front of the box show when it is safe to talk. While there might be other ways to enhance the security of discussions, such as RF shielding or turning the phone off, the true benefit of the box is that it doesn't prevent the phone owner from receiving messages or calls. An event on any of the phones in the box is detected and a blue light indicates an incoming message or call. The meeting attendees can then decide whether to pause discussions, open the box and take the call or ignore it.

SOUNDS ABOUT RIGHT...



By Lars Kroman

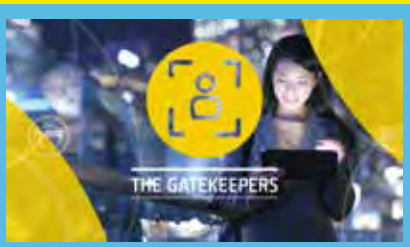
BEYOND TOMORROW VIDEOS:
WHICH SCENARIO DO YOU THINK IS MOST LIKELY TO HAPPEN?

VIDEO: What is Beyond Tomorrow, and how does it relate to the future of your product development strategy?

The Beyond Tomorrow future study identified a multitude of megatrends and created a plot of likely future scenarios. To help you stay mindful of your progress towards where your production testing needs to be in 2030, we've published five videos: an introduction video with a brief description of the project and four videos addressing how the scenarios are derived and an explanation of their difference.

SEE MORE
about the project, visit

www.beyondtomorrow.dk



SEE MORE
Check out
blog.bksv.com

The new Brüel & Kjær blog is up and running

Brüel & Kjær has many experts in the sound and vibration community, and they have things to say. We already have product data sheets, manuals, web pages, press releases and brochures, but for things in between or outside those tools, we now have the blog – a dynamic universe where you'll find everything from guides and best practices to help on getting to know your product.

Currently the blog has a sound level meter (SLM) theme, so if you need to know more about hand-held SLMs, the BKSV blog is the place to be reading. Check in from time to time to find out what will be next.

Brüel & Kjær merges with HBM

Søren Holst, president of Brüel & Kjær (left) and Andreas Hüllhorst, president of HBM (right)

From 1 January, 2019, Brüel & Kjær and HBM will be merging their activities into a new company. The merger will build on the best from each company and their respective capabilities. This will also be reflected in the name of the new company – HBK (Hottinger, Brüel & Kjær).

Both companies currently operate within the Test and Measurement segment of Spectris, the productivity-enhancing instrumentation and controls company. In addition, HBM Prenscia, the HBM subsidiary, will be fully integrated into HBK.

SEE MORE
about the merger, visit
www.hbk.one

IOMAC 2019, Copenhagen, Denmark

The 8th International Operational Modal Analysis Conference (IOMAC) will be held on 13 – 15 May 2019 in Copenhagen, Denmark.

IOMAC is a conference and parallel exhibition focusing on operational modal analysis (OMA) and related topics such as structural health monitoring (SHM).

From its beginnings in Copenhagen 2005, Brüel & Kjær has been a member of the permanent, scientific and organizing IOMAC committees. IOMAC is held every second year in Europe.

SEE MORE
For more information, please visit
www.iomac.eu/iomac-2019

BRÜEL & KJÆR NEWS

INTRODUCING THE BK CONNECT® APPLET AND LAN-XI LIGHT SOLUTION

With the creation of BK Connect® Applets and new LAN-XI Light hardware, Brüel & Kjær now has a low-cost solution that meets many 4-channel FFT, CPB and order tracking needs.

Built upon the successful LAN-XI data acquisition hardware and BK Connect analysis software, this solution guarantees world-class quality and usability. Each combination of hardware and applet contains all the functionality needed to acquire data, perform analysis and create a report. By only including the tools and functionality needed, users get a more focused and streamlined testing and analysis process, at a price in line with their needs.

BK Connect applets are licenced templates from the BK Connect sound and vibration software platform that meet specific analysis requirements for industry- and application-specific tasks. Users can expand capabilities through more applets or by trading them in and upgrading to the full platform, ensuring that there are always options should one's needs change.

Ideally suited for use with BK Connect applets, LAN-XI Light is a stand-alone, single-module, 25.6 kHz data acquisition front end that supports CCLD transducers. Its rugged, industrial and completely portable design makes it perfect for use in the field, as well as the lab. ■

SEE MORE
about BK Connect applets, visit

www.bksv.com/applets

Discom production testing – now in white goods

Brüel & Kjær's Discom line is a staple in the automotive production testing, and it continues to set the bar in that field. But recently, Discom technology has been installed on a white goods production line.

The Discom team developed new data evaluation and adaptive methods to deal with the changing environments of a white goods production line.

This first white goods instalment was completed in July 2018 and is a revolutionary way of improving production output and customer acceptance. ■

CUSTOMER NEWS

OSS SUPPRESSORS GIVE BK CONNECT A SHOT... AND LOVE IT

One of OSS Suppressors' main tasks is to determine whether the installation of their in-house manufactured suppressors results in a 'perceptible' reduction of the sound pressure level (SPL) of a gunshot. Having used the same solution for many years, OSS wanted to optimize its workflow even further. Enter BK Connect®.

The job at hand involves capturing the impulse SPL of 10 rounds (1 round/second) and then analysing the average peak [dB(A)] over the 10 rounds. Jimmy Miklavcic, Lead Test Engineer at OSS, and his team were often frustrated at the amount of time it took to switch back and forth between recording and analysing measurements. Managing two software programs with different user interfaces and different terminology is time-consuming. To improve efficiency, the OSS test shooters wanted to be able to take a few shots and get instant results in the field.

SEE MORE

www.bksv.com/casestudies

Successful lift-off for JAXA Epsilon-3 also provides a wealth of acoustic data

Photo licenced by JAXA / Reference number 0000019334

On January 18, 2018 at 06:06:11 (JST), JAXA launched Epsilon-3 from the JAXA Uchinoura Space Center. The successful launch carried its payload safely to orbit and provided data that will benefit future launches. In connection with JAXA, Brüel & Kjær application engineer Yutaka Ishii used four Type 8103 hydrophones and two Type 4948 aerospace surface microphones on the launchpad, an umbilical boom to measure the lift-off acoustic data and a horizontal line array for acoustic source identification. The goal of the research was to identify the acoustic source distribution between the base of the rocket and the output of the deflection tunnel, which is used to reduce the acoustic load on the rocket structure during take-off.

Read the article on page 32

FIVE QUESTIONS FOR JASON

BK Connect® Platform Product Manager Jason Kunio was born 15 miles west of downtown Chicago. Spare time is spent with his wife, three children and two rescue dogs, cycling with friends or watching his children compete in running races. A favourite indulgence is Lou Malnati's sausage and garlic Chicago-style deep-dish pizza.

MOTTO:
"MAKE NO LITTLE PLANS; THEY HAVE NO MAGIC TO STIR MEN'S BLOOD"*

What attracted you to Brüel & Kjær?
When I joined Brüel & Kjær 14 years ago, I was attracted to the diversity in day-to-day activity.

What drives you in your work?
I have compassion for our customers because I used to be a regular user of sound and vibration software. Improving customer experience is what continues to drive me and was the inspiration behind the development of BK Connect.

What is the best advice you've been given?
You can only change yourself, not others.

If you could have two super powers, what would they be and why?
I would like to fly because there are so many places in the world I want to see. And I would love to control the weather. I don't like it too hot or too cold and I am not a big fan of the rain.

What are you passionate about?
I want to make memories. I want to be doing things so when I look back on my life, I feel like I have lived all I can.

* Daniel Hudson Burnham (1846 – 1912), American architect and urban planner.

BW 0950-11