

SOUND AND VIBRATION NEWS

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WAVES

APRIL 2015

TESTING FUTURISTIC
FIGHTER JETS

SORTING OUT THE
SOURCES OF SOUND

REMEMBERING
PER V. BRÜEL

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Brüel & Kjær 

BEYOND MEASURE

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EDITOR-IN-CHIEF

Camilla Travis

MANAGING EDITOR

Peter Sims

COORDINATOR

Charlotte Stampé

WRITERS

Andreas Schuhmacher, Claire Flynn, David Borla, Douglas Manvell, Elisabeth MacMillan, Sheelagh Crewe

CONTRIBUTORS

Claus Blaabjerg, Dave Bogema, Henrik B. Herlufsen, Mette Temple, Noel Brown, Patrick Wethly, Svend Gade, Torben Rask Licht

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EDITORIAL OFFICE

Brüel & Kjær Sound & Vibration Measurement A/S
Skodsborgvej 307
DK-2850 Nærum
Denmark

Phone: +45 7741 2000

Fax: +45 4580 1405

Comments: waves@bksv.com

www.bksv.com/waves

Subscribe: www.bksv.com/subscribe

FRONT COVER IMAGE

An F-35 over Edwards Air Force Base

Brüel & Kjær 

BEYOND MEASURE

LETTER FROM THE MANAGING DIRECTOR

AN INSPIRATION TO US ALL



Welcome to this special tribute edition of Waves.

It is with great sadness that we report the passing of Per V. Brüel who, alongside his partner Viggo Kjær, founded our company. 100 years old, Per led a truly inspirational life and it's no exaggeration to say that the entire field of sound and vibration can be traced to his and Viggo's insight and innovation.

Per was a driving force behind our industry and his influence is felt in virtually every aspect of the business. A true pioneer, he developed many products that became the forerunners of the systems and solutions that Brüel & Kjær's customers depend on today, and his commitment to associations, standardization bodies and universities continues to shape their outcome even today.

In this issue, we pay tribute to Per's life and work by remembering some of his most far-reaching contributions. In this vein, we have also taken the opportunity to focus on initiatives our customers are taking to protect our environment and those who live in it.

For example, we cover how Lockheed Martin is using sound and vibration technologies to ensure their jet fighters are more effective in the air and safer on the ground. You can also learn how BHP Billiton is unearthing ways to reduce sound pollution from mines in Australia, and what is being done to accelerate traffic noise standards in cities across Europe.

These projects reveal a global impetus for collaboration and sustainable growth that Brüel & Kjær wholeheartedly supports. Only by fostering long-lasting partnerships that further our combined knowledge and by supporting our fragile environment can we all continue to drive our industry forwards with ever better and more innovative solutions.

Throughout his life, Per Brüel certainly lived up to his own high standards and I hope that this edition shows how we are helping our customers by aspiring to his legacy.

LARS RØNN
MANAGING DIRECTOR

TESTING FUTURISTIC FIGHTER JETS

A Lockheed Martin F-35 fighter jet is shown in flight, banking to the right. The aircraft is dark grey and black, with its landing gear extended. The background is a clear blue sky and a deep blue ocean. The text 'TESTING FUTURISTIC FIGHTER JETS' is overlaid on the top left of the image.

Collaborating with Lockheed Martin for many years, Brüel & Kjær is supporting the demand for 'right-first-time' engineering and supplying reliable, high-quality, goal-focussed solutions for noise and vibration testing and analysis. This partnership is helping ensure the high performance of some of the most technologically sophisticated machines ever built.



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

Lockheed Martin's core business areas include aeronautics, missile and fire control, and space systems, and the collaboration with Brüel & Kjær has included noise analysis tests for the F-35 fighter jet programme and vibration testing solutions for fighter jets, missiles and satellites.

GLOBAL PARTNERSHIPS

It is in Fort Worth, Texas, famous for its frontier atmosphere, that Lockheed Martin's sophisticated fifth generation combat aircraft is being manufactured. Creating an unprecedented fighter jet takes unprecedented collaboration and many different global partnerships have helped to create the F-35 Lightning II – a fifth generation, multirole fighter. It is perhaps little known that the world's best acoustic experts from Brüel & Kjær have contributed to the development of this aircraft.

One of the F-35 acoustic engineers at Lockheed Martin is Egbert Hood and he has been working with Brüel & Kjær for the last 5 years: "The acoustic specialists at Brüel & Kjær really understand our requirements and have impressed me with their ability to foresee our software and hardware needs, enabling us to stay aware of what is going on in the industry.

"Brüel & Kjær has also provided us with valuable remote support – even in one instance helping me to reconfigure the noise analysis system out in the field so that we could continue testing."

Egbert Hood adds, "As a whole, the F-35 programme is testing many different aspects of the jet fighter, and we are working with a great many people. For noise analysis around the aircraft, we can't dictate the testing schedule or redo an acoustics test, so it's important the hardware and software is reliable and that we get the testing right the first time. I'm happy to say that with Brüel & Kjær, we have been able to do this." ►

LOCKHEED MARTIN



TESTING FUTURISTIC FIGHTER JETS

ACOUSTIC FOOTPRINTS IN ALL CONDITIONS

The single-engine F-35 is manufactured in three versions:

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

All variants of the F-35 Lightning II use the world's most powerful fighter engine, the Pratt & Whitney F135. For the F-35B variant, the short take-off and vertical landing functionality gives the unique ability to operate from a variety of ships, roads and frontline combat zones, providing flexibility in many scenarios.

HOVERING

Similar to a helicopter that before landing can fly stationary, just above the ground, the F-35B short take-off/vertical landing (STOVL) variant has the ability to hover. This is made possible through the Rolls-Royce patented shaft-driven LiftFan® propulsion system and an engine exhaust nozzle that can swivel 90 degrees when in STOVL mode.

The Rolls-Royce LiftSystem® is the first to enable STOVL operations for supersonic-capable aircraft. Ground crew working in close proximity to these jets are exposed to more noise than with a conventional take-off/landing. ▣



Two F-35Bs
ferrying to
MCAS Yuma

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

As part of the F-35 programme, Lockheed Martin started using a Ramp Noise solution based on Brüel & Kjær's PULSE platform, which was later supplemented with the PULSE Reflex post-analysis software. "We started in 2009 with the LabShop software and around 75 microphones," explains Egbert. "Since then, we have had multiple test periods, analysing noise using different configurations of microphones. We are gathering information about noise close to the fighter jet during various manoeuvres and during particular aspects of the F-35 operation."

The integrated solution involves some 65–75 microphones laid out over the runway. The noise signals are collected by high-performance data acquisition hardware and the data is delivered to powerful analysis software, where the measurements can be easily reviewed and analysed.

One of the goals was to establish the acoustic footprint of the three F-35 variants, under all relevant operational conditions from take-off, landing, taxiing and fly-over, to the most challenging of them all: 'hovering'. The solution was used to seamlessly acquire and analyse a large amount of data for all F-35 variants under the different conditions, establishing the various noise footprints and helping to ensure noise exposure is limited within all these environments.

"It's a testament to Brüel & Kjær equipment that we are still using the same microphones that we started with and they are still working very well," explains Egbert Hood. "Over the years, the data acquisition has vastly improved. In the beginning, we used to review data at the end of a testing day and it would take a long time to process. With the latest data acquisition software, analysis times are so quick that we can process and review data during the actual testing. We really appreciate this increased efficiency and additional flexibility, and we have high confidence in the results that we receive." These results are used to inform decisions about the right hearing protection for ground crew and, for example, to define areas around the aircraft where certain actions should not occur. ►

“IT’S A TESTAMENT TO BRÜEL & KJÆR EQUIPMENT THAT WE ARE STILL USING THE SAME MICROPHONES THAT WE STARTED WITH AND THEY ARE STILL WORKING VERY WELL.”

EGBERT HOOD, ACOUSTIC ENGINEER, LOCKHEED MARTIN

Ground crew work in very close proximity to the F-35 fighter jet, for example, on aircraft carrier decks

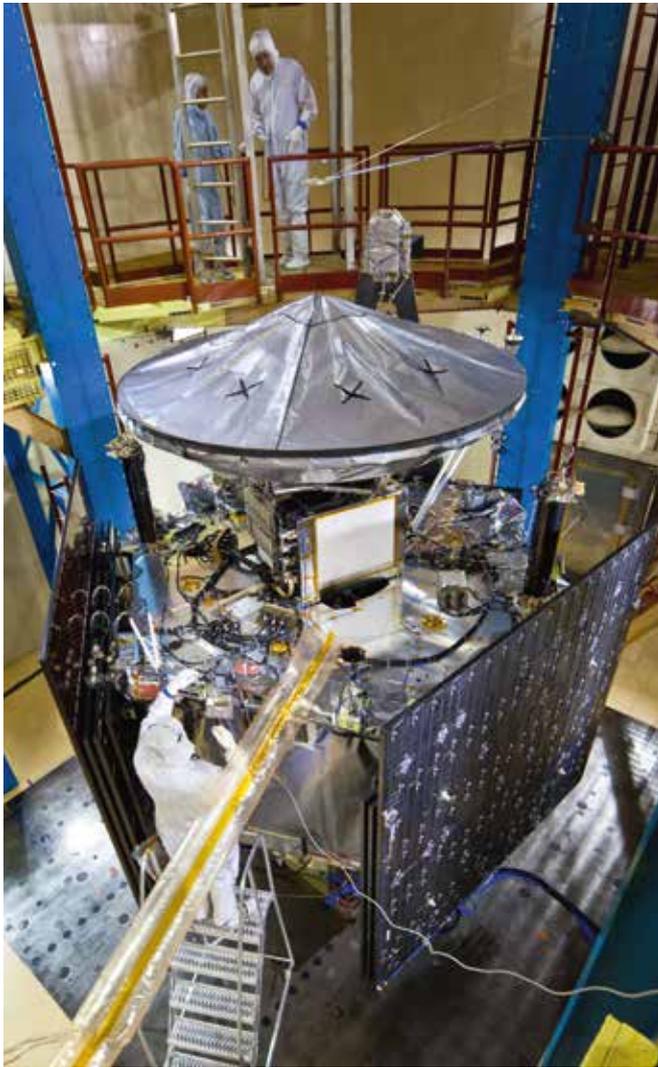


RAMP NOISE TESTING

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

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

TESTING FUTURISTIC FIGHTER JETS



The modular 450-channel PULSE™ vibro-acoustic data acquisition system supplied by Brüel & Kjær allows individual modules to be used freely, as standalone front-ends or collectively in frame-based configurations, making it suitable for testing large structures such as satellites and spacecraft



Crew aboard the USS Wasp prepare an F-35B test aircraft for flight as another jet flies in short takeoff/vertical landing mode. The two aircraft were participating in Developmental Test Phase two for the F-35B

VIBRATION TESTING DEMANDING APPLICATIONS

Lockheed Martin uses specialized domain expertise across all of its core business areas and Brüel & Kjær has not only been helping with acoustics but also when it comes to complex vibration testing to ensure the integrity and reliability of fighter jets, missiles and satellites. Extensive product qualification tests and stress screening tests are carried out to make sure that these demanding applications can sustain launch condition, deployment, transport, and long-term operation.

Vibration test solutions are in place for durability testing, stress screening and R&D qualification testing. Lockheed Martin has been putting the F-35 systems through exhaustive vibration test programmes and some of Brüel & Kjær's large V9x water-cooled LDS shakers (V984) are being used, for example, to test missile assemblies in Lufkin.

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

IDEAL FOR TESTING LARGE AEROSPACE SYSTEMS

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

The high number of channels supported, high data-sampling frequencies, tight phase matching between channels, and the ability to handle a wide dynamic range of inputs all make the PULSE solution ideal for large aerospace systems. The self-test and verification tools are dedicated to high channel-count

“NOISE AWARENESS IS A HIGH PRIORITY FOR LOCKHEED MARTIN AND BRÜEL & KJÆR SUPPORTS THIS AND PROACTIVELY HELPS US WITH THE LATEST SOLUTIONS.”

EGBERT HOOD, ACOUSTIC ENGINEER, LOCKHEED MARTIN

THE F-35 – THE MOST POWERFUL SINGLE-ENGINE FIGHTER EVER BUILT

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

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

systems, which ensure reliable performance, even in the most complex configurations.

MISSION-CRITICAL COLLABORATION

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

than a decade. As Egbert Hood comments, “Noise awareness is a high priority for Lockheed Martin and Brüel & Kjær supports this and proactively helps us with the latest solutions.”

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

SORTING OUT THE SOURCES OF SOUND

SEE MORE

- Small-scale speaker separation test results using BSS are included in the ISMA 2014 conference paper
- BSS analysis of the full-scale indoor pass-by test results are in the SIA Automotive 2014 conference paper

www.bksv.com/whitepapers





BY: **ANDREAS SCHUHMACHER**
 Research Engineer,
 M.Sc. Electrical Engineering., Ph.D.
 Brüel & Kjær

The latest research into Blind Source Separation (BSS) – a technique that involves separating a mixture of sounds – indicates that it is a good method for assisting the automotive industry in evaluating noise from different sources. Despite the complex algorithms involved, results suggest BSS may be a superior and more intuitive technique compared to the widely used Source Path Contribution (SPC) analysis.

When processing audio information of any kind, we have to deal with a mixture of sounds coming from a variety of sources. Signals from each source are mixed together to form a composite waveform and the frequency components of each source overlap. The challenge of working out which frequency component belongs to which sound source is highly complex.

SEPARATING THE SIGNALS FROM THE NOISE

Often, we are only interested in a single source of noise, so the challenge is to determine the target signal from all the signals in the mixture. Blind Source Separation (BSS) is a discipline within signal processing that involves separating a mixture of sounds and obtaining an estimate of each sound coming from various individual sources. The 'blind' refers to the fact that only a mixture of the sound is available and sometimes the number of different sources is unknown. A classic example is the 'cocktail party scenario', where the listener is able to focus on a single talker among many conversations. Here, the processing is done by the human brain. Using BSS, researchers have tried to capture this effect on measured microphone signals extracting any desired signal.

In the automotive industry, engineers and manufacturers must be able to evaluate the level of sound produced from many different components. For some parts of the car, noise-level reduction is a key concern in the design process, often to comply with official legislation. Knowing the partial contributions and sources of different noises when a car is in operation is essential in prioritizing the targets for overall noise reduction. ▶

THE COCKTAIL PARTY SCENARIO

At a cocktail party, the listener is able to focus on a single talker among many conversations. This processing is done by the human brain. ▣

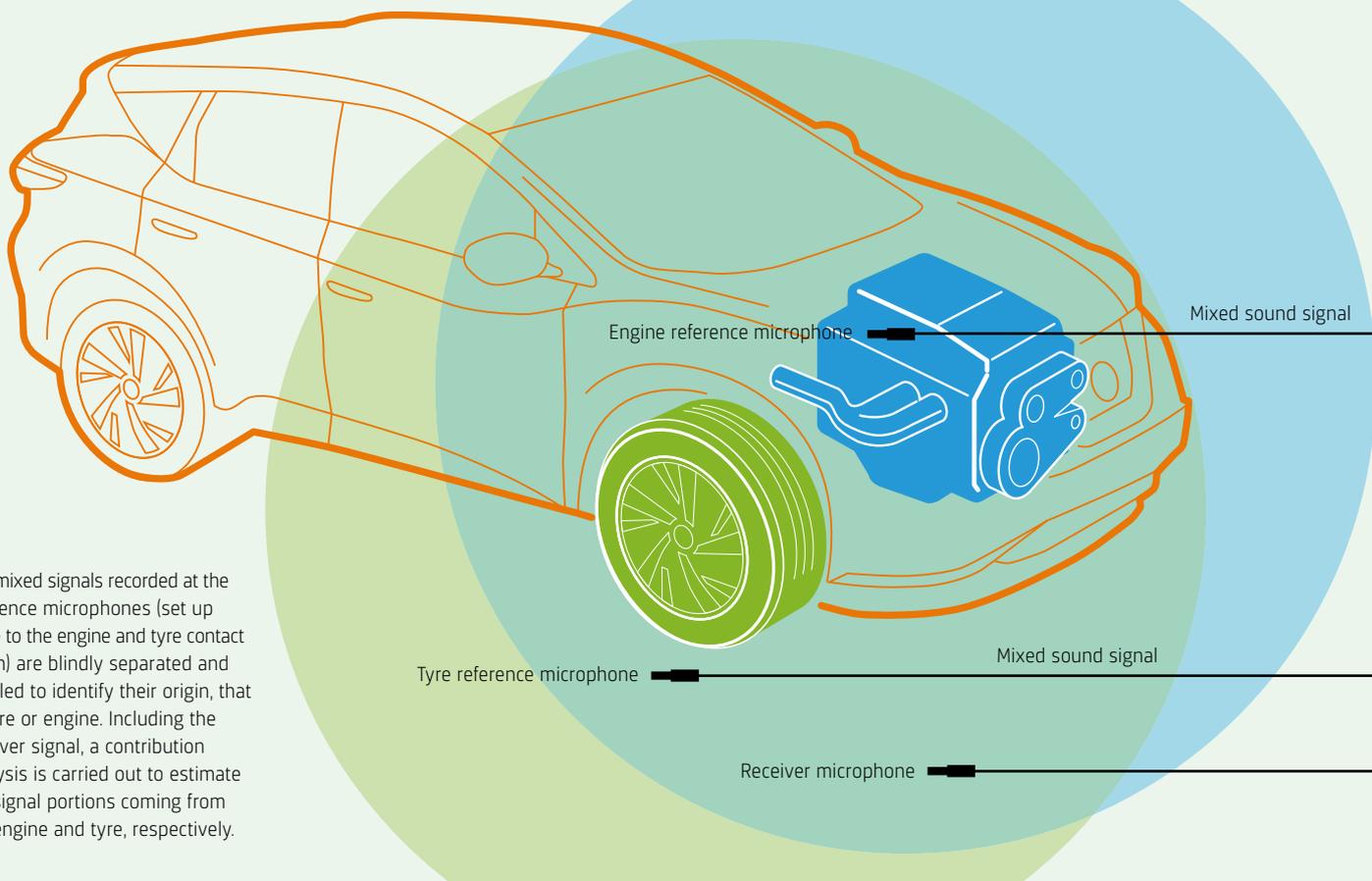


SORTING OUT THE SOURCES OF SOUND

BENEFITS OF BSS COMPARED TO SPC:

- Easier and more intuitive to perform
- No expert source separation experience required
- Superior separation results achieved ■

BLIND SOURCE SEPARATION



The mixed signals recorded at the reference microphones (set up close to the engine and tyre contact patch) are blindly separated and labelled to identify their origin, that is, tyre or engine. Including the receiver signal, a contribution analysis is carried out to estimate the signal portions coming from the engine and tyre, respectively.

CLASSIC METHOD

Currently, the technique widely used in the automotive industry to identify the sources of both interior and exterior noise is referred to as Source Path Contribution (SPC) analysis. Using SPC analysis, microphones are placed at different locations to measure, for example, tyre and engine noise.

Typically, a so-called speaker test is also conducted to establish noise measurements both inside and outside the car.

Although relied upon to provide good diagnostic information, SPC analysis has its drawbacks. It is labour-intensive and time-consuming to apply, and it also requires experienced personnel to correctly place microphones and speakers.

APPLYING BLIND SOURCE SEPARATION

BSS is already used in various biomedical application areas and within the telecommunications industry. Historically, this

technique has been driven by acoustic applications, such as hearing aids, and the subject of separating speech has been driving research in academia. What all these applications have in common is that a set of transducers is used to record a set of source mixtures and the problem is to extract each source at the transducers. In acoustics, the mixing at the microphones is complicated by the fact that the source signals enter the microphones at different

BLIND SOURCE SEPARATION

y_1 y_2

LABELLING THE SIGNAL

Tyre signal Engine signal

CONTRIBUTION ANALYSIS



Receiver signal decomposed into engine and tyre contribution signals

times, and reflections encountered in normal operating environments add copies of the source signals to the received microphone signals.

This means that the mixing process of sources into microphone signals is highly complicated. In addition, as the term 'blind' infers about the problem setup, usually only a recording of microphone outputs is available and no other informa-

tion of the acoustic paths between sources and microphones is given – researchers just have to assume that the signals produced by the sources are independent.

With the complex algorithms that are involved in BSS staying very much in the world of academia, the path to applying this technique to other industries has been slow and challenging.

COMPLEX ALGORITHMS

For several years, Brüel & Kjær has been researching BSS, believing it could be a more accurate and less time-consuming method for extracting different sound sources compared to SPC. Given the right algorithm, BSS could, for example, help solve the problem of separating engine and tyre noise using a set of close microphones.

Since the 1990s, a vast number of technical papers have been published on BSS. Many different algorithms have been proposed, all solving very specific separation problems. However, a very limited number of applications solving industrial problems exist and, since most algorithm development has been devoted to the separation of speech or music, it was challenging to find a useful source separation algorithm that could be applied to industrial noise challenges, including those in the automotive industry.

THE RIGHT PLATFORM

An opportunity appeared when Brüel & Kjær was invited to take part in an EU-funded research project to identify the contribution of different engine modules to the exhaust noise from a turbo-shaft helicopter engine during operation. This was the platform that was needed to further develop the

knowledge of BSS and help to apply it to the aerospace and automotive industries.

The plan was to install sensors into the engine and develop different methods to perform the source separation task. Brüel & Kjær suggested the BSS approach, which was accepted by the other participants and the EU-funded project became known as TEENI (Turbo-shaft Engine Exhaust Noise Identification).

Following the kick-off meeting for TEENI, in April 2008, a systematic research approach was conducted, from a literature review to algorithm investigations and a selection of small-scale tests involving speakers inside a duct. Finally, the selected algorithm for performing the BSS task was given a full-scale test on the helicopter engine data and compared to other noise source breakdown techniques. ▶

THE FINAL MEETING OF TEENI WAS HELD IN EARLY 2013. RESULTS IN BRIEF CAN BE FOUND HERE:



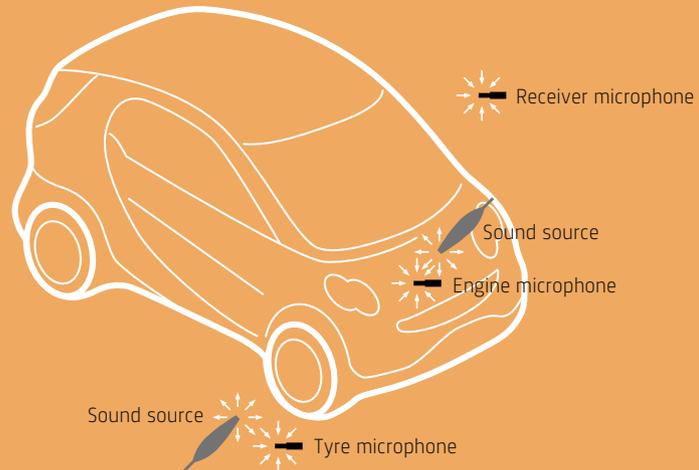
SORTING OUT THE SOURCES OF SOUND

SOURCE PATH CONTRIBUTION

SPC for a full vehicle involves measurements with a sound source at around 20 microphone positions, moving the sound source for each measurement.

Additionally, a vehicle operational measurement is needed to perform contribution analysis.

In comparison, blind source separation only requires the vehicle operational measurement. ■



VERIFYING THE ALGORITHM

While the EU project was ongoing, Brüel & Kjær began to test the algorithm using datasets from previous projects, using the BSS processing of microphone signals to help resolve the contribution of noise from different parts of an operating car. The challenge was to validate the results. How can you, for example, accurately measure the noise from tyres without the engine?

A small-scale set-up was designed using speakers around a Smart Car. The speakers

played tyre and engine signals and close microphones recorded the mixtures. The recorded microphone signals were used to train the BSS separation filters and perform the separation into tyre and engine contribution sounds at the microphones. The result was an improved separation, with only very little cross-talk compared to the classical separation approach based on SPC modelling.

The conclusion from this test was that BSS was superior to SPC analysis in terms

of separation performance, and also easier to perform.

Following this success, an SPC dataset used for contribution analysis during an indoor vehicle pass-by test was used to separate real recordings measured with microphones in an engine room and around tyres during a standardized fast acceleration. Separation results, for example, listening to the tyre noise component at the microphone close to the tyre compared to the actual recording, which was contaminated with engine and intake noise components, suggested a good separation result was obtained.

Finally, towards the end of 2013 and in early 2014, access to another, more comprehensive dataset also helped to compare the measurements from SPC processing with those from the BSS method. The dataset contained many reference measurements and assisted in further validating the results for multiple sources.

Using the same microphone positions and data for tyre noise and engine noise

“WE HAVE HIGH EXPECTATIONS FOR THIS JOINT PROJECT WITH BRÜEL & KJÆR AND ARE CONFIDENT THAT WE WILL SUCCEED IN ESTABLISHING A STRONG METHOD FOR EVALUATING NOISE FROM DIFFERENT SOURCES.”

YOSHIHIRO SHIRAHASHI,
SENIOR ENGINEER, NISSAN MOTOR CO., LTD.

THE CONCLUSION FROM TESTING IS THAT BSS IS SUPERIOR TO SPC ANALYSIS IN TERMS OF SEPARATION PERFORMANCE – AND ALSO EASIER TO PERFORM.

that had been used for SPC analysis, it was possible to repeat a specific pass-by test to evaluate car noise for any source including engine, intake, exhaust and tyre, etc. This full-scale test of indoor vehicle pass-by measurements using BSS estimated the noise contribution from each tyre. Comparisons to SPC modelling results were extremely positive and confirmed that the BSS method was a reliable way to separate the sources of sound and, what's more, the separation results were superior to those obtained with SPC analysis. The Brüel & Kjær method to apply the BSS concept to determine noise source contributions of vehicles is currently patent pending.

LOOKING AHEAD

A systematic approach to validate the estimated noise contributions is planned for spring 2015, when Brüel & Kjær will conduct a joint project with Nissan Motor Co., Ltd. in Japan. Tests will be performed to compare BSS against the traditional 'masking' method, so that researchers can obtain direct information about the separate noise contributions. The masking procedure involves wrapping noise sources (for example, the engine) with heavy layers or mounting silencer systems. Testing sources of sound in this way is, of course, a

cumbersome contribution analysis technique that is unrealistic to use regularly, but it does offer a good way of verifying the accuracy of the BSS method. Yoshihiro Shirahashi, Senior Engineer with the Noise and Vibration Performance Engineering Group at Nissan comments, "We have high expectations for this joint project with Brüel & Kjær and are confident that we will succeed in establishing a strong method for evaluating noise from different sources."

Using BSS to access the partial contributions of car noises will be further validated for robustness and it is anticipated that the range of applications for BSS will expand. The BSS principle can also be applied to environmental noise from roads and airports. In this situation, the measurement microphones pick up a mixture of noise sources and BSS can be used to aid further processing and provide valuable information for traffic noise-level compliance. BSS could also help to assess and improve the sound quality of an engine by measuring on or around the engine surface with sensors and extracting components related to hidden processes. Future plans also include pursuing cooperation with universities working on BSS methods in different contexts, and attracting students to work on joint BSS projects. ■



WHO SAYS WHAT?



"I HAVE PLENTY OF CLEVER GENERALS BUT JUST GIVE ME A LUCKY ONE."

NAPOLEON BONAPARTE
AUGUST 15, 1769 - MAY 5, 1821

French military and political leader Napoleon Bonaparte rose to prominence during the latter stages of the French Revolution and its associated wars.

Napoleon is widely acknowledged for his powerful leadership skills and great vision. On pages 24 – 28 you can read about the life of one of the founders of Brüel & Kjær, Per V. Brüel, who sadly passed away on April 2 this year. Per was inspired by Napoleon's quote and the company had an unofficial rule of conduct when hiring, "We wanted talented people who could think for themselves, who were creative – and also a bit lucky." ■

SOME OF THE WORLD'S NOISIEST CITIES

MUMBAI (BOMBAY), INDIA

An article in the Mumbai Mirror describes Mumbai as “unfit for living, at least on the cacophony front.” Traffic Infra Tech magazine suggests that the three main contributors to the noise pollution are construction projects, firecrackers and loudspeakers during festivals, and indiscriminate honking. And the worst honking offenders? Auto rickshaw and taxi drivers.

KOLKATA, INDIA

This honk-happy city, according to The Telegraph, Calcutta, has honked its way

THE WORLD HEALTH ORGANIZATION SUGGESTS THAT HEALTHY NOISE LEVELS SHOULD NOT SURPASS 55 DECIBELS DURING THE DAY AND 40 AT NIGHT.

to the top of the decibel charts. A survey by the West Bengal Pollution Control Board reveals that one of the city's busiest crossings averages 18,857 honks in 24 hours, or one honk every five seconds. During daytime, the average is one honk every three seconds.

CAIRO, EGYPT

Noise pollution has reached alarming levels in this the 24-hour metropolis and has led to hearing problems, irritability and even death. According to a study by the Egyptian National Research Centre,



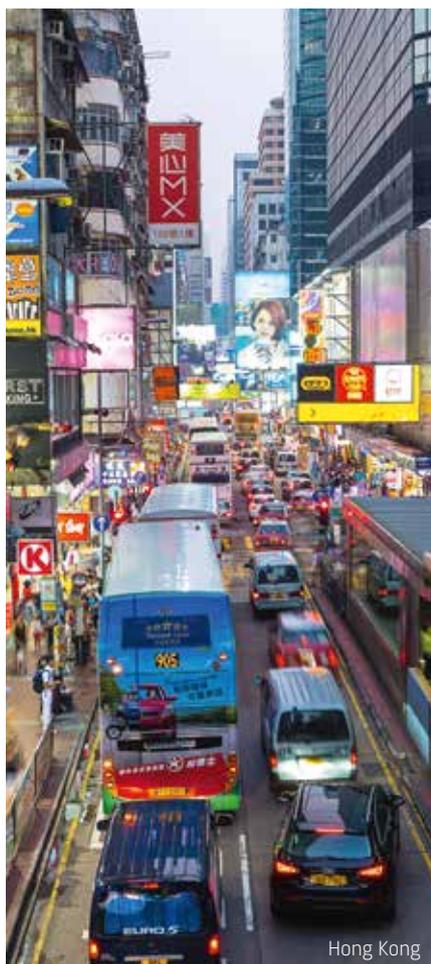
average noise levels are at 90 dB and never drop below 70 dB. This can be compared to spending all day inside a factory.

NEW YORK CITY, UNITED STATES

The “city that never sleeps” is the most populous city in the US and noise is consistently the number one quality of life issue. New York authorities received more than 40,000 noise complaints in 2012, ranging from garbage trucks and police sirens to “lawn-care equipment” and “other animals”.



New York City. Photo by T erabass



Hong Kong

DELHI, INDIA

The level of noise produced has been called dangerous and traumatic leading to hearing loss in citizens 15 years earlier than expected. A recent study showed that not a single area of Delhi passed the Central Pollution Control Board's standards of noise control.

TOKYO, JAPAN

In this town of 35 million people, noise pollution caused by public loudspeaker messages, construction work and transport has forced many of its citizens to wear earplugs as they go about their daily lives.

BUENOS AIRES, ARGENTINA

Increase in construction, cars and people make this city the noisiest in the region. Buses hurtle along cobbled streets and trains run through the city. The heat and humidity also forces many residents to leave their windows open, or turn on the incessantly whirring air-conditioners.

SHANGHAI, CHINA

This busy city with a population of over 24 million results in 100,000 noise complaints each year. So-called social life noise (general street noise) is the most annoying form of noise and accounts for about half of the complaints. This category includes noise from speakers outside stores, pets and barking dogs, public dancing, outdoor karaoke and music, tea shops and sports fans.

KARACHI, PAKISTAN

With five million vehicles on the road, it's no wonder that traffic is the main cause of noise pollution in Karachi. A study conducted in Karachi reports that about 83% of street policemen, 33% of rickshaw drivers and 57% of shopkeepers in busy shopping areas had noise-induced hearing loss. ■

This article is based on publicly available information

EXPERT PROFILE

MAN ON A MISSION



Throughout his life, Professor Amiya Mohanty's sights have been firmly set on pioneering new waves in sound and vibration. Whether creating ground-breaking technologies far ahead of his peers or guiding students through the peaks and troughs of new scientific understanding, his journey is an inspiration to us all.

With over 100 publications, patents and consultancy work for at least 50 companies, Professor Amiya Mohanty's long and distinguished career has covered virtually every aspect of sound and vibration from underwater acoustics to experimental modal and CAE techniques.

Today, Professor Mohanty works at Indian Institute of Technology (IIT) Kharagpur, India's oldest and most prestigious engineering institute, where he continues to push the frontiers of sound and vibration excellence. His fascinating life has been spent in the pursuit of knowledge – for himself, for the industry and for his students – and his mission is far from over.

A PASSION IS BORN

Professor Mohanty completed his Bachelor's degree in Mechanical Engineering with an undergraduate project that involved programming a Vax 1180 with a 'homebrew' weight optimization algorithm for an engine con rod. Later, for his Master's degree, he built himself an analyzer using a cheap data acquisition

“I ALWAYS THINK OF INNOVATIVE WAYS TO EXCITE MY STUDENTS BY EXPLAINING CONCEPTS THROUGH BOTH SIMPLE MATH AND REAL LIFE EXAMPLES.”

AMIYA R. MOHANTY, PROFESSOR MECHANICAL ENGINEERING, IIT KHARAGPUR

board and a PC that was used to monitor the vibration of a gearbox. This was 1987 and modern tools such as MathCAD, MATLAB® and LabVIEW did not exist, so Prof. Mohanty simply rolled up his sleeves and took it upon himself to create his own FFT analyzer.

When asked how he first got involved with sound and vibration engineering, Prof. Mohanty recalls: “While working on vibration monitoring for my Master’s, I contacted Brüel & Kjær using an old reply card from the Monitor newsletter I found lying on my professor’s table. I was surprised to receive a big parcel containing sound and vibration literature. I still have these items today and use them frequently. From the material, I saw the potential of computers in condition monitoring applications.”

THE AMERICAN YEARS

In 1989, Professor Mohanty moved to the US after receiving a three-year scholarship to study for a PhD under Professor Andy Seybert at the University of Kentucky. On arrival, he was immediately assigned the task of programming a PC interface for the original impedance tube system pioneered by Professor Seybert. Professor Mohanty concluded his PhD with a thesis on the use of boundary element modelling methods for exhaust systems.

Unbeknown to him, the years spent at the University of Kentucky would equip Professor Mohanty well for later life. His time there had given him a chance to learn about noise control and engineering consultancy as well as to explore one of his many talents: the ability to teach.

When asked about his love of the classroom, Professor Mohanty says, “I have always had a knack for teaching. In fact, at the University of Kentucky, I was awarded the Chancellor’s award for outstanding teaching.”

After a postdoc at Purdue University, Professor Mohanty joined the CAE department at the Ford Motor Company.

“I was enjoying CAE and NVH testing at Ford when my father died suddenly in 1995,” he recalls. He returned to India to take care of his family and thanks to his strong academic background and broad experience, he could get a faculty position at IIT Kharagpur to continue his work. ►



AMIYA R. MOHANTY

PROFESSOR,
PH.D.

Current position

Professor Mechanical Engineering at IIT Kharagpur, India (since 1996)

Specialization

Machine diagnostics, signal processing, NVH, CAE and underwater acoustics

Previous employment

Ford Motor Company, Detroit USA; Larsen & Toubro Ltd, Mumbai India

Education and research

- Post-doctoral fellow Purdue University USA
- Ph.D. Mechanical Engineering from the University of Kentucky 1992
- M. Tech Machine Design IIT Kharagpur 1988
- BSc Engg (Hons) Mechanical Engineering National Institute of Technology, Rourkela India 1986

Awards and honours

- Chancellors Award for Outstanding Teaching, University of Kentucky, USA (1992)
- OAP In-bound Research Fellowship, National University of Singapore (2003)
- Rais Ahmed Memorial Award, Acoustical Society of India (2009)
- Best Research Paper Award (Underwater Acoustics), Acoustical Society of India (2011)

Membership of professional bodies

- Member, National Committee on Noise Pollution Control, CPCB, Government of India
- Member, Bureau of Indian Standards on National Building Code, Government of India
- Member, Mentor Council on Automobile, Ministry of Labor and Employment, Government of India ■

MAN ON A MISSION

EDUCATING THE INDUSTRY

At IIT Kharagpur, Professor Mohanty was not left in peace to pursue university research, and word quickly spread about his knowledge and ability: "In India there are few experts in this area, so many companies contact me to solve their noise and vibration problems."

However, he quickly saw how unprepared many businesses were to tackle sound and vibration issues. This is reflected in the preface to his recently published book, Machinery Condition Monitoring, where he emphasizes the need to close knowledge gaps in India's sound and vibration management industry. When asked to expand on this, he gave a couple of examples of his encounters when consulting: "Once I was working with earth-moving machinery and I requested an oil sample for spectral analysis. The technician took a fire bucket, full of sand and emptied it out to collect the oil. When I tried to explain to him the need for uncontaminated containers, he said 'such a big engine, a little bit of sand won't hurt!'

"A slightly different case involved an automotive customer who set a target for noise reduction. When this was achieved, they asked if they doubled the money could we halve the noise again. I had to explain that NVH is not simple arithmetic."



Professor Mohanty performing a sound quality measurement on an engine exhaust

These experiences inspired Professor Mohanty to try to raise the profile of sound and vibration engineering through undergraduate courses at IIT Kharagpur as well as several short industry courses. His efforts were by no means in vain and a new acoustic and vibration monitoring laboratory has since been commissioned, and now there is a thriving international collaboration and exchange program with universities from all over the world.

Professor Mohanty continues to teach many of these courses and when asked about the role of the modern lecturer he gives an interesting reply: "With the ease and abundance of information now available, a teacher has to play a careful balancing act. I always think of innovative ways to excite my students by explaining concepts through both simple math and real life examples.

"When I teach, I always bring my experiences from consulting and research projects to the classroom, which you won't find in the standard engineering texts. Conversely, while discussing engineering problems with the students, many new ideas and alternative solutions also come to me."

We asked some of Prof. Mohanty's former students what it was like to study under him. The consensus was: "damn hard work, but worth it as employers recognize and value the fact that we have studied under him."

LOOKING AHEAD

Professor Mohanty has accomplished so much but he still retains his passion and drive to improve India's sound and vibration industry.

Next on the list is assisting the development of the Indian 'bullet train', which is to be partly engineered at IIT Kharagpur. There is also the commercialization of two indigenous technologies using jute, a locally grown plant, for noise insulation and electric motor current signature analysis, the latter being a clever technique for vibration monitoring of pumps and drives driven by electric motors.

A man in such high demand will never stay still for long, but one thing is clear – Professor Mohanty's mission is not over yet. ■





DRIVING BRAND AWARENESS.

By **DAVID BORLA**
 VP, Sales & Marketing
 Borla Performance Industries



**DRIVING
BRAND
AWARENESS**


Borla positioned their exhaust sound simulator in the most noticeable location within their SEMA display to entice enthusiasts and encourage them to hear and feel how different exhaust notes change the character of the car

“YOU LIVE WITH THE SOUND OF YOUR VEHICLE FROM THE MOMENT YOU TURN IT ON TO THE MOMENT YOU SHUT IT OFF. THAT MATTERS TO PEOPLE – IT EXCITES THEM.”

DAVID BORLA, VP, SALES & MARKETING, BORLA PERFORMANCE INDUSTRIES

At Borla, we develop and build the world’s finest aftermarket exhaust systems for high-performance vehicles. In fact, we are the originators of this market, which has given us a unique understanding of what it takes to create the right product for a highly discerning customer.

The sounds our exhaust systems deliver are truly distinct. It’s what matters most to the people who buy our products, and it’s among the benefits we are known for. However, it has always been a challenge to demonstrate to our customers how the sound we create is critical to the relationship between a car and its driver. But now, thanks to a collaborative development project with Brüel & Kjær, an exciting solution has been found in the Borla Driving Simulator that was a big hit at the 2014 SEMA Show.

IT’S NOT JUST SOUND – IT’S CONNECTION

Our customers are primarily automotive enthusiasts and competitive racers. Their needs are diverse, but at the end of the day, one thing they all want from their exhaust system is the right sound. Much like with music, however, the precise qualities this sound must have are very subjective and have a huge effect on the individual’s driving experience.

For example, with competitive racing, timing the perfect shift can depend greatly on hearing the engine’s pitch, and that shift could be the deciding factor separating first from second place. For everyday road drivers, the sound their car makes can greatly influence how they drive, how much they enjoy the ride and, of course, how they themselves are perceived.

MODELLING ‘THE SOUND OF BORLA’

Getting this just right is something Borla has been refining into an art for over three decades. In fact, people today even refer to ‘the Sound of Borla’ as the benchmark of exhaust note quality. Our new relationship with Brüel & Kjær has resulted in even more sophisticated modelling technologies, enabling us to

streamline our development process.

We are also using new measurement and analysis techniques to bring a higher level of precision to what we do by going deeper into the mathematics and theory behind it. In short, Brüel & Kjær is helping us utilize advanced technology to understand what we do to a greater degree than ever before.

A VIRTUAL SOUND EXPERIENCE

One particular Brüel & Kjær product caught our attention: an NVH Simulator that replicates the sound of a car’s exhaust to an extraordinary degree, taking into account a wide variety of factors such as accelerator pedal position, gear shifts or even driving uphill. As the simulator was designed for engineering purposes, our initial interest in it was purely as a developmental tool; however, we quickly realized its potential for the upcoming SEMA trade show.

SEMA, held in Las Vegas, is the world’s premier trade event for automotive speciality products. Competition is fierce, so a simulator seemed the perfect way to drive brand awareness and have people experience the real life unique sound of our exhaust systems. At this trade show, vehicles are not allowed to be run, so supplying a virtual driving experience with actual pulse-quickening connection between engine and ear was both unique and powerful.

REINVENTING THE WHEEL

The first step was to feed the simulator with the right data to reproduce the correct Borla exhaust sounds. Brüel & Kjær travelled to our facility in California to make the necessary recordings and measurements of the chosen model car, a 5-litre Mustang, with the stock exhaust

“BEING ABLE TO DEMONSTRATE THE LEVEL OF CARE AND DETAIL WE DEVOTE TO OUR EXHAUST NOTES WAS A PHENOMENAL SALES TOOL AND SOMETHING WE WANT TO EVOLVE WITH BRÜEL & KJÆR.”

DAVID BORLA, VP, SALES & MARKETING,
BORLA PERFORMANCE INDUSTRIES

system as well as three different Borla exhaust options. This data was then adapted, analysed and integrated to create a unique and incredibly realistic Borla Driving Simulator.

Once completed, we added the final touches – a large screen, an adjustable racing seat, touchscreen control panel, steering wheel, foot pedals and speakers – to make it comfortable and appealing as well as compact and durable enough to be transported.

MAKING NOISE AT SEMA – AND BEYOND

More than 60,000 people attended SEMA, including many from OEMs, suppliers and race teams. The simulator worked perfectly and was one of the event’s most popular attractions. Interestingly, people initially thought that it was simply a racing video game; but when they understood its intent – a unique way to experience first hand the different Borla exhaust sound options and how they affect both driving style and enjoyment – they absolutely loved it.

Borla had been looking for a way to more directly engage customers at the SEMA Show and the simulator proved itself to be the perfect sales tool. Not only did it fire up everyone who experienced it and leave them with a great impression of the Borla brand, but it also has breathed new life into how we approach our development and marketing activities.

These are very exciting times for Borla, and we look forward to finding out just how far down the road our relationship with Brüel & Kjær will take us. ■



REMEMBERING

A SOUND AND VIBRATION PIONEER

CELEBRATING THE
LIFE AND WORK OF

PER
V. BRÜEL

A CHARISMATIC PERSONALITY

According to those who worked with him and knew him well, Per Brüel was charismatic, bright and fast-thinking. He was an exceptional engineer, although anything but a nerd, passionate about cars, motorcycles, airplanes (a pilot himself) and red wine. His faith in his own instincts and insight extended to hiring people who he sensed would be right for the company, "I like lucky people, the ones who dare to take chances, believing that they will be successful. It is said that Napoleon, when he was to promote an officer, always asked, 'is he a lucky man?' instead of asking for the officer's record. I must confess I have used the same method when I hire young engineers and I have had good results. It may not seem nice, but the result is that I have been very fortunate and have ended up with a long series of excellent assistants and colleagues. Thank you, Napoleon." ■

Having just celebrated his 100th birthday, Per V. Brüel passed away on April 2, 2015. He was a visionary engineer and inventor, responsible for engineering breakthroughs in the late 1930s and early 1940s with the development of the world's first acoustic analyzer and the first commercial piezoelectric accelerometer (Type 4303).



Photo © Manna Film, Philip Jørgensen

“HE LITERALLY CREATED THE FIELD – INDUSTRY DIDN’T MEASURE SOUND AND VIBRATION AT ALL IN THE DAYS WHEN HE STARTED.”

TORBEN RASK LICHT, M.SC. E. E.,
PRODUCT MANAGER OF VIBRATION
CALIBRATION SYSTEMS

It’s no exaggeration to say that the entire discipline of sound and vibration can be traced to these and other innovations developed by Per Brüel and his partner Viggo Kjær; innovations that laid the foundation for sound and vibration measurement and analysis technologies that contribute to the smartphones we use, the cars we drive, the aircraft we fly in – even the environment in which we all live. “He literally created the field – industry didn’t measure sound and vibration at all in the days when he started,” says Torben Rask Licht, M.Sc. E. E., Product Manager of Vibration Calibration Systems for Brüel & Kjær, who worked alongside Brüel for more than two decades. “In today’s terminology, he branded the idea.”

It was an idea that provided the genesis of a global company founded by Brüel and Kjær, a company that has been the world’s largest specialist in sound and vibration solutions for decades and is still animated by the example of its founders. “Brüel & Kjær today is a reflection of Per Brüel’s action and vision,” says Lars Rønn, Managing Director of Brüel & Kjær. “Our company culture, our pride in product quality and our focus on innovation all stem from those early days.

If this company is synonymous with sound and vibration, it is at least in part because we still so closely identify with the beginning that Per Brüel and his partner Viggo Kjær gave us.” From belief in giving employees freedom to explore, to focus on solving customer problems and commitment to opening global markets, Brüel & Kjær still operates along unmistakable guidelines that the two partners established.

AN ENGINEERING PLAYGROUND

Nowhere is that influence more apparent than in Brüel’s attitude towards work and employees. “We wanted to make products that had an impact on society and we wanted to make money,” said Brüel. “We also aimed to create steady jobs, so we wouldn’t have to fire people. If I had to choose a motto for my work, it is that it must in no way be boring.”

Speaking on behalf of his partner, Viggo Kjær, he added an unofficial rule of conduct, “Running a business is about having fun. Having fun is the best way to use your skills. We wanted talented people who could think for themselves, were creative and also a bit lucky. Employ good people; don’t tell them what to do when they start work, because people will find that out for themselves, making them highly inspired.” ▶

REMEMBERING A SOUND AND VIBRATION PIONEER



At Per Brüel's home just outside Copenhagen, on March 6, about a hundred family and friends from the sound and vibration community celebrated the latest achievement in a distinguished life

By all accounts, this philosophy has remained intact throughout Brüel & Kjær's history. "Brüel & Kjær was an engineering playground," says Henrik B. Herlufsen, M.Sc. E. E., Application Engineer at Brüel & Kjær. "This was supported by Per's belief in creativity and having fun. He had faith in people founded on giving them time and freedom to experiment and explore. Let's call it freedom with responsibility. There was no rank and hierarchy and very little top-down guidance, but initiative was expected from everyone – a spirit that's still fundamental to the company today." Brüel's belief in initiative and self-reliance also produced a conservative financial philosophy.

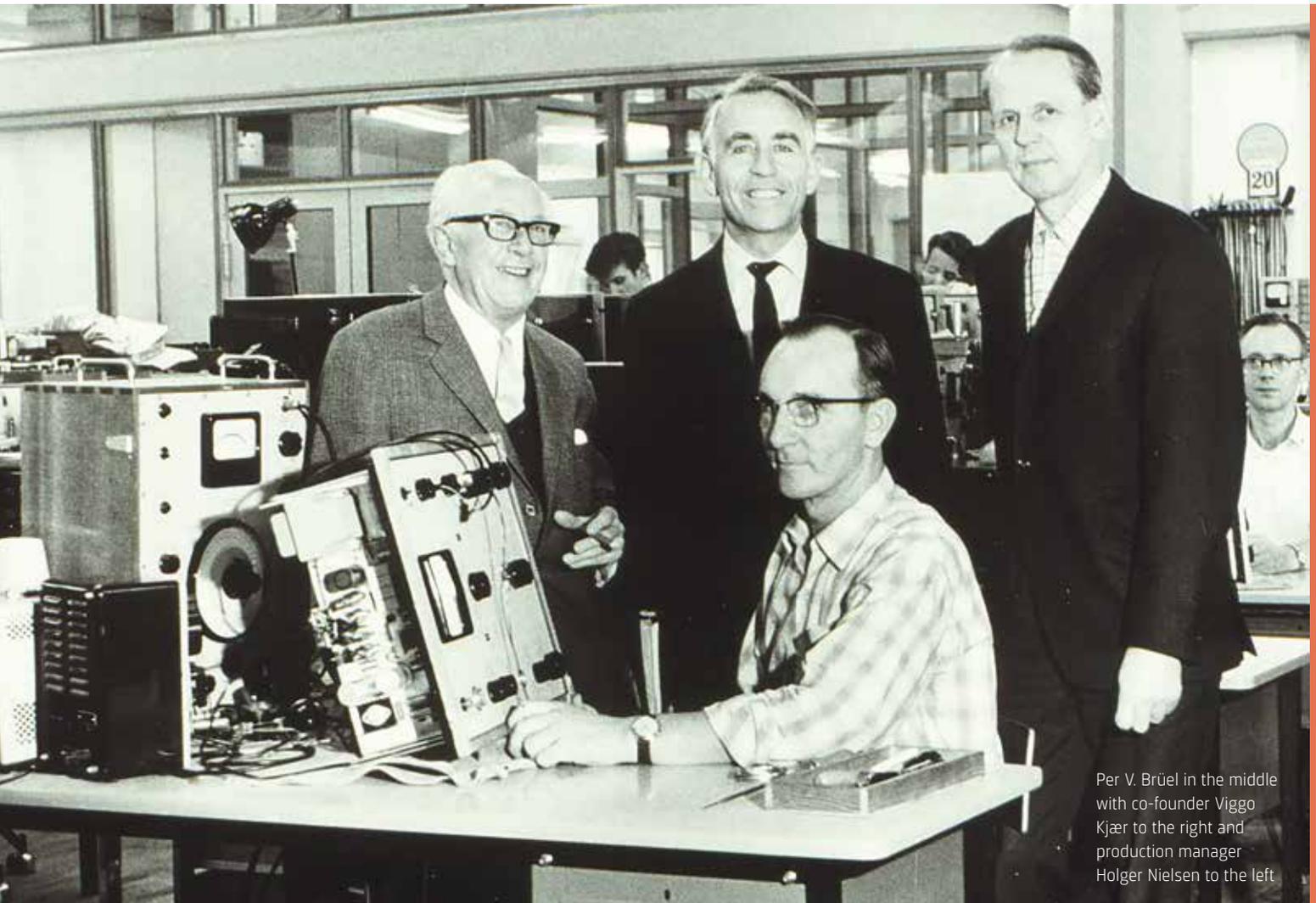
At one point, Kjær sold his accordion and Brüel parted with his Leica camera to keep the business going. "I was scared stiff of borrowing money," says Brüel. "I thought, if we did, we would die. It's far too expensive. We didn't want to be dependent on bankers; we wanted to be 100% self-financed." An understandable attitude in light of the severe financial crisis that gripped the world economy in the 1930s, when the two partners started out. While Brüel & Kjær is now too large a company to be self-financed, the founders' attitude of financial prudence continues today.

GLOBAL ASPIRATIONS

Still fundamental to the company is Brüel's drive to expand into global markets and to develop products based on customer needs. He was a globalizer long before the word globalization gained currency. "We were young – we felt we could do anything," he said. "That attitude lies within our logo, a globe with a wire going around it two and a half times. We would not settle for less. We prepared to go global from the very beginning." One advantage of being so far ahead of the technology curve was that, as Viggo Kjær observed, "Internationally, we didn't have many competitors." This was a competitive vacuum that Brüel single-handedly rushed to fill, making marathon driving trips that criss-crossed the US and repeated trips as far afield as Russia and China in search of new markets. From the 1950s onward, Brüel, an accomplished pilot, flew company planes from what was humorously referred to as B&K Airlines on many of these journeys, not only within Europe but also as far as Thailand and North America. "He was a pioneer and a global representative for the company, a pilot who flew far and wide to open new markets," says Rønn. "Sales distribution today is founded on what he did – as a result, a significant amount of Brüel & Kjær's sales today are in Asia." ►

“WE WERE YOUNG – WE FELT WE COULD DO ANYTHING, THAT ATTITUDE LIES WITHIN OUR LOGO, A GLOBE WITH A WIRE GOING AROUND IT TWO AND A HALF TIMES. WE WOULD NOT SETTLE FOR LESS. WE PREPARED TO GO GLOBAL FROM THE VERY BEGINNING.”

PER V. BRÜEL



Per V. Brüel in the middle with co-founder Viggo Kjær to the right and production manager Holger Nielsen to the left

PER BRÜEL INNOVATIONS

Examples of key technologies that Per Brüel helped to pioneer – and that either are still in use or provided the basis for current Brüel & Kjær products:

- Constant Percentage Bandwidth (CPB) analyzer – incorporated today in PULSE™ and 2250/70 Hand-held Analyzers
- Standing Wave Apparatus – for material testing, designed in 1944 based on Brüel's Ph.D. thesis and still in use some places today. Replaced by newer but similar instrument and principles in mid 90s
- Level Recorder – in production 1949–1985 – now replaced by digital technology, but principles remain the same
- Accelerometers and microphones – still the best transducer technology for measuring sound and vibration. ■

REMEMBERING
A SOUND AND VIBRATION
PIONEER



“HE WAS A PIONEER AND A GLOBAL REPRESENTATIVE FOR THE COMPANY, A PILOT WHO FLEW FAR AND WIDE TO OPEN NEW MARKETS.”

LARS RØNN
MANAGING DIRECTOR OF BRÜEL & KJÆR



A member of Brüel & Kjær staff measuring noise using a sound level meter, circa 1971

A pioneer in creating customer feedback from his journeys, Brüel was determinedly customer-centric long before the term was coined. “He was always inspired on his return from visiting customers and finding out what they needed,” says Svend Gade, Solution Specialist and Associate Professor at Brüel & Kjær.

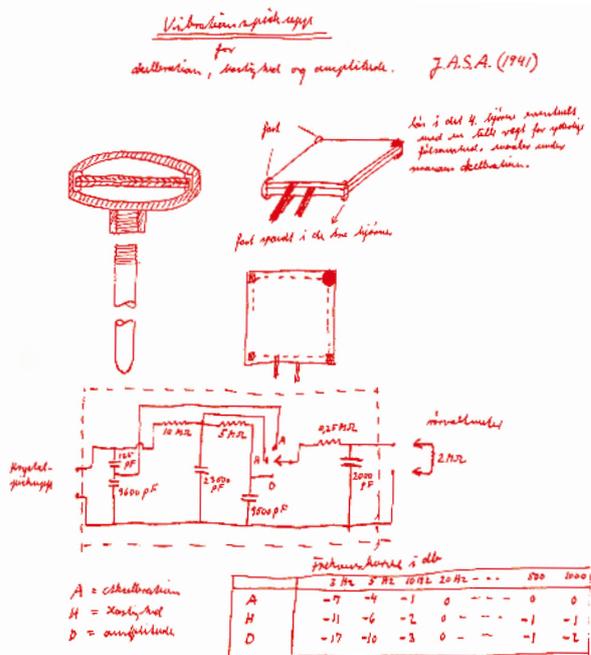
“Today, we still develop new products based on market feedback – we have customer clinics to find solutions according to customer requirements and customers are invited in to help test new products. Innovation for Brüel & Kjær has always been about understanding customer challenges.” The fact that Brüel & Kjær stays close to its customers through 13 local sales offices and more than 100 distributors and agents worldwide is in no small measure thanks to Brüel’s path-breaking example.

100 YEARS OF ACHIEVEMENT

Finally, there is no doubt that everyone at Brüel & Kjær would be happy to claim spiritual kinship with a man who, on March 6, looked back on a century during which he played multiple larger-than-life roles: engineer and visionary inventor, founder of a major global corporation, enthusiastic pilot and explorer who personally pioneered new markets and whose accomplishments continue to help us expand our most exciting frontiers.

Brüel & Kjær data acquisition and vibration test systems have been used to test NASA’s Mars Curiosity rover. And when a lander from the European Space Agency’s Rosetta space probe recently touched down on a comet, Brüel & Kjær accelerometers were there to ‘listen’ to its landing. Not a bad legacy. Thank you Per and may you rest in peace. ■

Background information for this article was drawn from ‘Journey to Greatness: The Story of Brüel & Kjær’, by Jackson Mowry and Ghita Barring



Hand drawing of the first Brüel & Kjær accelerometer (Type 4303), developed in 1943



THE LOUDEST SOUND, NATURALLY

The explosion was reportedly heard 4800 km (3000 miles) away, where people described the sound as “cannon fire from a nearby ship”.

The Batavia gasworks (north Jakarta), 160 km (99 miles) away from the source, registered a sound pressure level spike of more than 2½ inches of mercury (8.5 kPa), equivalent to 172 decibels. The sound pressure wave travelled the globe seven times in total over the following five days.

Nature is a law unto itself, and there is nothing we can do to combat its extremities, in this case extreme sound. However, we can do something about sounds created by man. On pages 34 – 38 you can read about the big noise in Europe where new laws and standards are shaping traffic. ■

The loudest sound in recorded history came from the volcanic eruption on the Indonesian island Krakatoa at 10.02 a.m. on August 27, 1883. The explosion caused two thirds of the island to collapse and formed tsunami waves as high as 46 m (151 ft) rocking ships as far away as South Africa.



Krakatoa today



Coral block thrown onto the shore of Java after the Krakatoa eruption of 1883

LISTENING TO THE COMMUNITY

SEE MORE

Read the conference paper
'Noise sentinel – a proactive
approach to noise management in
mining operations at BHP Billiton
Worsley Alumina Pty Ltd' at

www.bksv.com/whitepapers





Boddington
Bauxite Mine
digger and truck



The Shire of Boddington,
Western Australia

At BHP Billiton, the way results are achieved is just as important as the results themselves, and the impact of mining on surrounding communities is a concern that is taken very seriously. In Western Australia, measures to reduce noise for neighbours to a bauxite mine involved close consultation with the public, monitoring noise at residential locations and creating community forums.

As one of the world's largest producers of major commodities, BHP Billiton integrates social and environmental considerations into all its business operations and stakeholder interactions. At the BHP Billiton Worsley Alumina Pty Ltd bauxite mine in Western Australia, community engagement has been an essential part of fully understanding and effectively addressing concerns about noise.

NEAR NEIGHBOURS

Spread over approximately 10,000 ha, the bauxite mine is located near the town of Boddington, about 130 km from the capital city of Perth. A 51 km overland bauxite conveyor system links the mine to an alumina refinery near the town of Collie. Mining has been part of the Boddington landscape for three decades. However, the expansion of mining operations in 2012 led to a rise in complaints from residents about noise, especially about mining activities at night.

This increase in complaints also resulted in an increase in operational downtime for Worsley – partly because hand-held noise monitoring was required to determine whether mining operations were in compliance with the prescribed limits, leading to extensive operational delays during complaint investigations.

MONITORING IN REAL TIME

Worsley decided to collaborate with Brüel & Kjær to customize a Noise Sentinel system to monitor noise generated by mining and ensure that the impact on neighbours was minimized by incorporating alert systems to allow for proactive management.

The monitoring network consists of 12 fixed, real-time noise monitors and 5 mobile, directional noise monitors, collecting real-time noise and weather data and transmitting the information to a live Internet-based system, which is monitored on a 24-hour basis by Worsley personnel. In addition, a community website was developed to display noise data, overlaid on an aerial map of the mine.

The noise monitors are programmed to generate alerts based on set thresholds for defined periods of time. Each alert has an associated 30-second sound recording to help determine the source of the noise and the cause of the alert. Worsley staff review each alert and its associated sound recordings and close alerts with relevant comments for later analysis. Where mining is the cause of the alert, actions are taken to ensure that operations are modified to be below prescribed limits. ►

**LISTENING TO
THE COMMUNITY**

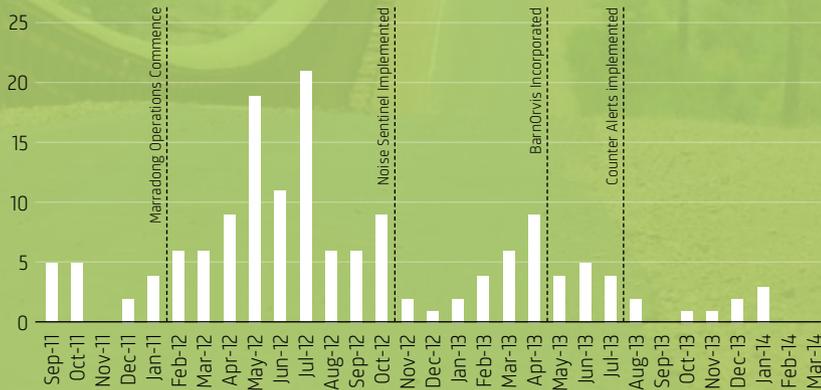
51 km bauxite conveyor between mine and refinery

BACKGROUND NOISE

Silver Kenny, Environmental Analysis and Improvement Specialist at Worsley, explains about one of the challenges, “Given the relatively low noise limits applied in Western Australia, it was important to differentiate noise from sources other than mining such as traffic and bird song”. The alert rules in the Noise Sentinel system were refined so that, for example, where passing road traffic was a significant noise source, threshold levels for alerts were increased to 60 dB(A) during the day to cover the peak traffic hours. Given that this time period had the lowest risk (highest prescribed limits), this approach was considered acceptable.

In addition, frequencies greater than 2 kHz were filtered to remove the majority of bird song and an additional filter was applied to prevent alerts when wind levels were greater than 5 m/s and when rain levels were greater than 0.25 mm/15 min. Together, this minimizes the impact of weather-related noise and reduces the number of alerts not related to mining activities.

MINING NOISE COMPLAINTS RECEIVED BY WORSLEY



Boddington Bauxite Mine
- Primary Crusher





“THE TOTAL NUMBER OF COMPLAINTS ABOUT NOISE FROM THE MINE DROPPED SIGNIFICANTLY FROM 77 IN FY2013 TO 20 IN FY2014.”

SILVER KENNY, ENVIRONMENTAL ANALYSIS AND IMPROVEMENT SPECIALIST, WORSLEY

ESSENTIAL DIALOGUE

Community concern about Worsley's mining noise was a major factor that drove the implementation of the Noise Sentinel system, and engaging local people was a key part of the successful solution. Community Liaison Committee meetings and forums helped to explain the purpose and value of the monitoring network and a stakeholder webpage provided residents with a traffic light system for all noise monitors, reflecting the alert status shown on Worsley's monitoring screens. This transparency of the mine operations allowed the community to see when noise levels were below (green), close to (yellow), or over (red) prescribed limits.

DROP IN COMPLAINTS

Worsley's Mine Community Liaison Committee, which includes representatives from across the community, has received positive feedback about Worsley's improved management of the impact of mining noise. Worsley continues to meet regularly with its near neighbours to update them on mining activities and to get their feedback. From this engagement, it is clear that the local community trusts that noise is being managed proactively.

“The total number of complaints about noise from the mine dropped significantly from 77 in FY2013 to 20 in FY2014*,” explains Silver Kenny. In particular, since the installation of the Noise Sentinel system, the number of Level 2 complaints (where noise levels are above the prescribed statutory limit) has dropped from 18 in FY2013 to 6 in FY2014.

*FY = financial year which runs from 1st July – 30th June

Based on the positive outcomes of implementing the Noise Sentinel system, Worsley received a Highly Commended award at the 2013 BHP Billiton HSEC Awards under the Environment category. This was welcome recognition of the work done to enhance environmental noise management and an acknowledgment of the improvements in community interaction. More recently, a mini perception survey was undertaken at an open day at the bauxite mine and this recorded a marked improvement in community perceptions since FY2013 for all metrics related to environmental and social performance. ■

This case was first presented at inter.noise 2014 as a conference paper written by Silver Kenny, BHP Billiton Worsley Alumina Pty Ltd, Australia and Douglas Manvell, Brüel & Kjær.

Worsley mining operations showing locations of noise monitors and near neighbours.
Yellow dots: Near Neighbours
Red dots: Noise Monitoring Terminals
Blue dots: BarnOwls
Grey outline: Timber Reserve Boundaries



COMPLIANCE IN WESTERN AUSTRALIA

The Environmental Protection (Noise) Regulations specify legal noise limits (L_{A10} dB(A))* for mining activities in Western Australia:

- 07:00 to 19:00 hrs Mon. to Sat. – 45 L_{A10} dB(A)
- 09:00 to 19:00 hrs Sun. and Public Holidays – 40 L_{A10} dB(A)
- 19:00 to 22:00 hrs All days – 40 L_{A10} dB(A)
- 22:00 hrs any day to 07:00 hrs Mon. to Sat. & 09:00 Sun. & Public Holidays – 35 L_{A10} dB(A)

* L_{A10} assigned level means an assigned level which, measured as an $L_{A\text{slow}}$ value, is not to be exceeded for more than 10% of the representative assessment period (3 or 4 hours) ■



Bauxite is refined to recover the alumina present. Once the alumina – aluminum oxide trihydrate – is recovered, it can be electrolytically reduced into metallic aluminium. Australia is the world's biggest producer of bauxite with almost one-third of the world's production

THE BIG NOISE IN EUROPE: NEW LAWS AND STANDARDS SHAPING TRAFFIC



ASSESSING ROAD NOISE LEVELS

Researchers assess noise levels at different intervals. EN12523 defines two indicators:

- L_{den} – the average noise levels over all days, evenings and nights in a year
- L_{night} – the average yearly night time noise level (nights having a minimum duration of eight hours) ■

A look down Avenue des Champs-Élysées as seen from the Arc de Triomphe

Traffic noise is one of the most widespread environmental problems in Europe and it's more than just an annoyance; it has become a major health concern. Research is driving changes in legislation to adopt new standards and help mitigate the impact of road noise on health. What's being done to meet new standards and what are the implications for associated industries?

As more information about the health impact of road noise becomes available, it is clear that EU-wide measures are necessary to minimize the negative consequences on public health. The fact is there are more cars on the road and European roads are becoming noisier. According to the World Bank, in the EU in 2011 there were 552.5 vehicles on the road per 1000 people, compared to 513.2 per 1000 inhabitants in 2005. Today, the EU considers the impact on health from road noise as second only to that from poor air quality.

HOW DOES NOISE AFFECT HEALTH?

Noise from traffic affects people's health both directly and indirectly. It affects our nervous and hormonal system, which can increase the risk of cardiovascular disease and damage cognitive function. Health problems include sleep disturbance, tinnitus, heart disease, and raised blood pressure, as well as disrupted learning and memory (especially in children).

In 2011, the WHO's Global Burden of Disease report estimated that each year Europeans lose at least one million healthy life years due to disability or disease caused by traffic noise – and this is considered to be an underestimate of the real total.

QUANTIFYING THE PROBLEM

In 2002, the Environmental Noise Directive 2002/49/EC (END), a major step forward in identifying and quantifying environmental noise pollution in the EU, was ratified. The aims of END include:

- Monitoring the environmental problem
- Informing and consulting the public
- Addressing local noise issues
- Developing a long-term EU strategy



The proximity of vehicles and residential properties means that road traffic noise affects a large number of people

This EU directive is implemented in each EU country, with every Member State defining action plans. To assess road noise, all countries must prepare strategic noise maps for major roads using harmonised noise indicators: L_{den} (day-evening-night equivalent level) and L_{night} (night equivalent level). Based on these noise maps, local entities are responsible for preparing action plans to reduce road noise and to set targets together with the community. ►

THE BIG NOISE IN EUROPE: NEW LAWS AND STANDARDS SHAPING TRAFFIC

EU LEGISLATION TO LIMIT NOISE

Stricter vehicle noise standards encourage manufacturers to produce noticeably quieter vehicles. The European Commission currently has several new vehicle noise emission requirements including:

- Motor vehicle noise: Directive 540/2014
- UN-ECE Regulation 51 including new ASEP regulations to ensure the relevance of compliance
- Tyre noise standards: Regulation 661/2009 (2012)
- Tyre labelling: Regulation 1222/2009 (2012)
- A range of additional requirements for other vehicle types, such as motorcycles ■



IN 2014, THE EUROPEAN COMMISSION ADOPTED STRICTER NOISE EMISSION STANDARDS TO ENCOURAGE VEHICLE MANUFACTURERS TO PRODUCE NOTICEABLY QUIETER VEHICLES.

For example, in Denmark, the Danish Road Directorate (Vejdirektoratet) responsible for all state-owned roads has prepared noise maps of the entire national road network – approximately 3800km in total, identifying housing areas that are particularly badly affected by road noise.

NOISE LEGISLATION AND STANDARDS

Legislation is used to manage road noise by placing limits on noise sources, potentially affecting hundreds of industries. Legislation refers to standards to define how to determine noise emission (noise coming from different sources) and immission (noise at receiver points, for example, houses):

- Legislation defines what is allowed (for example, by placing limits on noise sources).
- Standards are the agreed methods for determining road noise emission in total and from different sources, and for determining noise levels in the environment at receiver points.

By following agreed standards, global manufacturers can better understand which way legislation will go and be ready for new requirements. The standards for noise levels help to ease communication and ensure that all stakeholders agree on a common methodology to measure noise and to isolate the various sources of noise (normalizing other factors). Overall road noise is a mixture of several factors, for example:

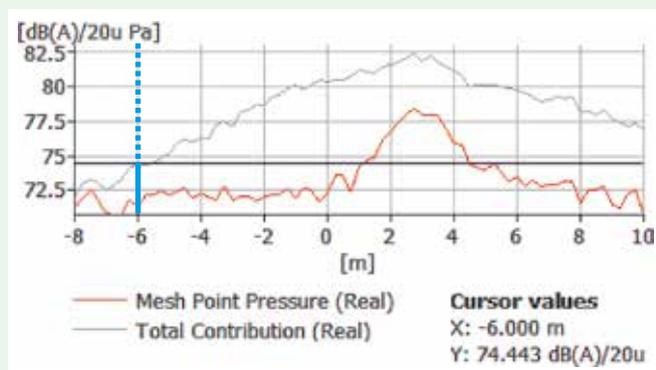
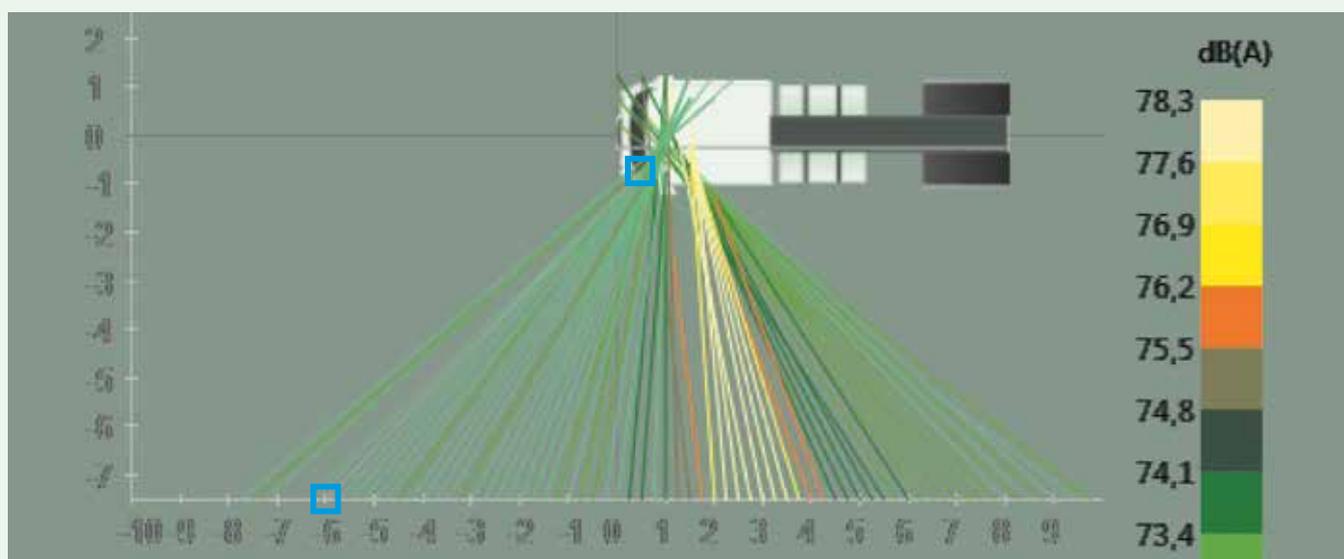
- Infrastructure (noise barriers, speed limits, etc.)
- Tyre type
- Asphalt type
- Vehicle type (car, truck, motorbike, van, etc.)
- Operational conditions due to the driver (such as acceleration, braking and revving) or due to the weather conditions (for example, if roads are wet)

LIMITS TO TACKLE TRAFFIC NOISE

Different limits are placed on different types of vehicles and on tyres. For several years, the European Commission, in cooperation with stakeholders such as the European Automobile Manufacturer's Association (ACEA), has had a range of such regulations.

In 2014, the European Commission adopted stricter noise emission standards to encourage vehicle manufacturers to produce noticeably quieter vehicles. The subsequent legislation means that noise limit values will be tightened by an additional 3 to 4 dB(A) from 2016 to 2026 for passenger cars, vans, buses,

TROUBLESHOOTING WHEN PASS-BY LEVEL CRITERIA ARE NOT MET



Line diagram showing the sources on the truck delivering the highest sound pressure levels at a given position on the test track.

ISO Sound Pressure Level vs position compared with SPL of source highlighted in upper graph. In this example the highlighted source delivers highest SPL of all sources at -6 m

coaches and trucks. New limits will be phased in by July 2016, 2022 and 2026 and the EU estimates that these measures will reduce vehicle noise by 25%.

The EU also recommended legislation to tighten the rules regarding tyre noise and a labelling system was agreed to inform consumers about the best and worst performers. The labels have been on all tyres for sale in Europe since 2012. This has the potential to be an important contribution to noise reduction because, above speeds of 30 – 50 km/h, tyre noise/road is the most significant source of noise.

ACTION ACROSS EUROPE

The challenges of road noise are being tackled in different ways across Europe. For example, on one of the busiest ring roads around Paris, four action plans have been proposed to reduce noise levels: a reduction of speed from 80 to 70 km/h; encouraging night-time drivers to reduce their speed to 50 km/h; using low-noise road surfaces; and an increase in the number of noise barriers. ►

THE BIG NOISE IN EUROPE: NEW LAWS AND STANDARDS SHAPING TRAFFIC



BRÜEL & KJÆR'S INVOLVEMENT WITH LEGISLATION AND STANDARDS

To be ready to supply optimal solutions and support at the right time, Brüel & Kjær monitors legislation and any proposed new developments. Since legislation typically refers to standards that cover the assessment methodology, Brüel & Kjær is deeply involved in standardization and maintains a good network with leading researchers and practitioners.

Brüel & Kjær staff around the world review proposals and influence their development through ISO Working Groups. In addition, Brüel & Kjær participates in ISO Acoustics (TC43) Plenary Meetings, which formally approve resolutions regarding standardization and manage assessment standards. The Brüel & Kjær corporate ISO Standardization Coordinator, Douglas Manvell, is on the ISO TC43 Advisory Panel, which advises on policy. ISO TC43 (acoustics) has 17 active working groups developing 43 standards and typically publishes between 15 – 30 formal documents (standards in various stages of development) for review each year.

One example of how Brüel & Kjær standardization work is organized is the proposed new tone identification method for use in all ISO standards – from environmental noise to noise from computers and office equipment. Here, a 9-man strong Brüel & Kjær task force, representing Product Management and R&D, ensures that the standard is reviewed, understood and assessed technically and commercially for implementation in solutions in the future. ■

In the UK, for example, the Noise Abatement Society is promoting quieter goods delivery vehicles. This was a topic at the 2014 'Quiet Cities' global summit, where DHL launched a 'city safe, city quiet' gas-powered concept vehicle. In order to reduce noise levels, the truck has been specifically designed with nylon components, pneumatic technologies, and a tail-lift running on a motor operating between 60 and 65 dB(A). Furthermore, a directional, tonal alarm – which allows noise outside the hazard zone to dissipate quickly – has been fitted.

BRÜEL & KJÆR STAFF AROUND THE WORLD REVIEW PROPOSALS AND INFLUENCE THEIR DEVELOPMENT THROUGH ISO WORKING GROUPS.

Another example is 'NordTyre', a joint project between the Nordic countries that plans to investigate the connection between noise from car tyres and typical Nordic road surfaces, with the goal of better understanding how tyres with a low noise level contribute to combatting noise problems, and how this contribution can be optimized.

TOUGHER NOISE LIMITS TO COME?

What is consistent across Europe is the need to meet new EU standards and to keep up to date with future legislation. In addition to noise emission limits getting stricter, work is ongoing to investigate and manage noise specifically from tyres and from asphalt.

The automotive industry and others are continually developing solutions to meet market demands, fulfil test codes and their limits, and provide documentation and labelling in accordance with standards and legislation. Engineers in many fields share a common interest in noise pollution reduction and will continue to design new technologies that produce less noise.

WORKING TOGETHER WITH MANUFACTURERS

Where will the focus of noise-limit legislation be in a few years? Perhaps there will be more attention on road surfaces rather than tyre or engine noise, since this has been demonstrated to have a big impact on noise levels. All stakeholders must continue to agree on how to measure noise and find ways to reduce levels efficiently, without reducing quality of life. Companies such as Brüel & Kjær can contribute to greater accuracy, helping manufacturers to better meet limits and comply with future legislation. Brüel & Kjær is also heavily involved in discussing and developing future standards – gaining the insight that is vital to be able to advise customers and develop effective solutions that help efficiently meet noise limits in the future. ■

A NEW WHITE PAPER FROM THE STACKS

A PRACTICAL GUIDE TO USING MIMO VIBRATION CONTROL FOR MIL-STD-810 SINGLE-AXIS TRANSPORT TESTING OF LARGE, RESONANT, LAND-BASED MILITARY PAYLOADS

Multi-shaker, single-axis testing can improve the quality of test, but the added complexities should be considered early in the development of a new vibration test system.

There is increasing demand to use vibration systems for transport testing of larger and more complex shaped structures, to replace the need for extensive test track proving. In such cases, the use of multiple shakers working in combination in a single axis may provide a better solution than trying to use a single bigger, higher force shaker. This is increasingly being recognised by vibration standards such as the US military environmental test standard MIL-STD-810.

When performing Multi Exciter Single Axis (MESA) testing, there are two main approaches for controlling the vibration, each with pros and cons depending upon the application. Simplistically, these approaches involve:

- Providing a common drive signal to all shakers
- Providing a different drive signal to each shaker

The latter approach requires use of a MIMO vibration controller and introduces system interactions, which may affect the choice of shakers, accelerometers, fixturing and even operational personnel. It is, therefore, important to consider these interactions as early as possible in the development of a new vibration system to ensure that the design of the system is optimized and the operational capability is understood.

This paper presents practical information on using a multiple shaker MIMO vibration testing approach for transport testing of large structures and provides guidance to organizations expanding from single shaker system testing to multiple shaker testing. It shares lessons learnt through hundreds of hours of real-world sine and random testing using a 420 kN force Quad LDS V9 vibration system in both horizontal and vertical configurations. It targets the real-world practical considerations of the test engineer/manager when defining and developing a MIMO vibration test facility for large payload testing. ■

SEE MORE

Read the full white paper at

www.bksv.com/whitepapers



Flexible new triaxial accelerometer



The replacement for the popular Type 4506 is the new Type 4529-B, which is even better! Its single-axis power supply gives the flexibility to measure with only one or two axes connected – saving data acquisition channels for more input

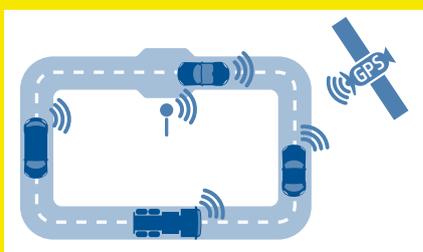
signals. A choice of mounting surfaces and a selection of clips give many mounting options, while its more robust design is nine times less sensitive to temperature fluctuations and 20 times less sensitive to base bending. ■

Keep your data in sync with GPS

Now engineers can distribute LAN-XI data acquisition hardware frames over a large area without any cables connecting them – and still perfectly synchronize their measurements.

A GPS receiver in each LAN-XI system time-stamps its data, allowing individual datasets to be perfectly merged later. This makes testing much simpler wherever there are large distances between measurement

points, such as aircraft flyover certification and explosion testing, and enables multi-vehicle pass-by testing on the same track. ■



New Analyzer Solutions catalogue available

The catalogue formerly known as the 'PULSE catalogue' has been renamed the Analyzer Solutions catalogue and now includes PHOTON+ and hand-held analyzers as well as our extensive offerings of PULSE software and LAN-XI hardware.

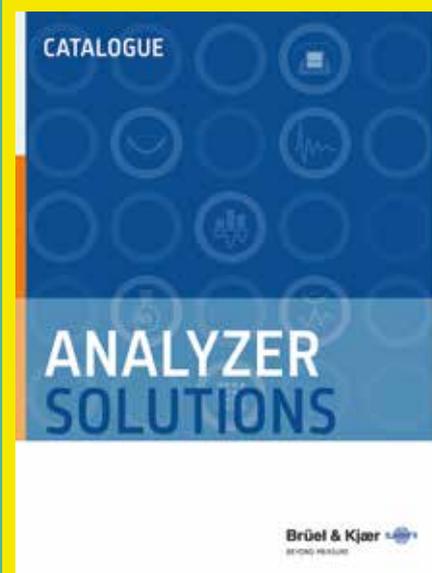
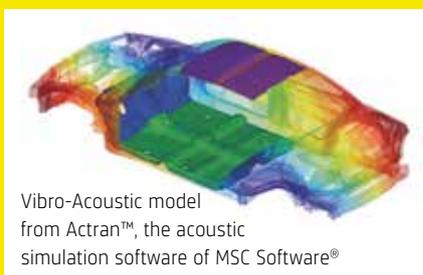
The catalogue features a sleek new design to go along with its new name. Ask your local sales representative for a copy or find it on our website. ■

Experience the design with CAE Auditor

Computer Aided Engineering (CAE) tools are used extensively throughout the vehicle design process. PULSE 19 therefore introduces a new CAE Auditor into NVH Simulator.

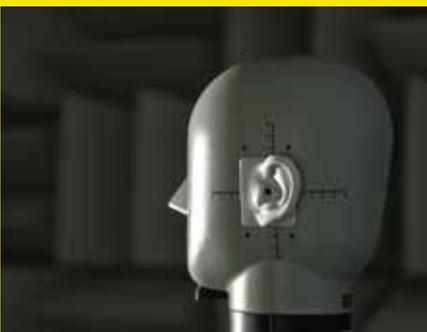
CAE Auditor allows users to import their CAE simulation results directly from a standard output file and combine them with other NVH Simulator models – from test or CAE sources – in order to listen to them in the context of a complete vehicle. This allows vehicle development teams to audition the NVH performance of their design concepts in a virtual vehicle.

CAE Auditor's unique change-modelling technique allows the impact of individual design changes to be evaluated by using the difference between baseline and modified model results as a filter on measured test data. ■



CUSTOMER NEWS

MICROSOFT TRANSFORMS YOUR WORLD WITH HOLOGRAMS



Microsoft® amazed the tech world at a Windows® 10 event by unveiling HoloLens®, an ‘augmented’ reality headset that has been hailed as a game changer in the way people interface with technology. The sleek, futuristic-looking headset overlays objects and images on top of what you already see so you can explore new worlds while staying firmly rooted in reality. With HoloLens it is possible to play Minecraft on your coffee table using virtual blocks, or design virtual components on a real-life motorbike.

Unlike Oculus Rift®, a full virtual reality headset, HoloLens helps users interact with the real world in a different way. The ‘first fully untethered holographic computer’ brings high-definition holograms to life using only hand gestures and voice commands. Cameras track your every move and built-in spatial sound lets you hear holograms wherever they are in the room, with pinpoint precision.

Microsoft is being secretive about what’s actually in HoloLens but one thing is certain: Brüel & Kjær’s HATS was there during testing. Because HoloLens is a completely wireless system, Microsoft has obviously been working hard to crack the challenges of effective voice recognition.

Set to be released in the same timeframe as Windows 10 later this year, Microsoft is ready to make augmented reality the new reality for tech-savvy consumers and gamers everywhere. ■

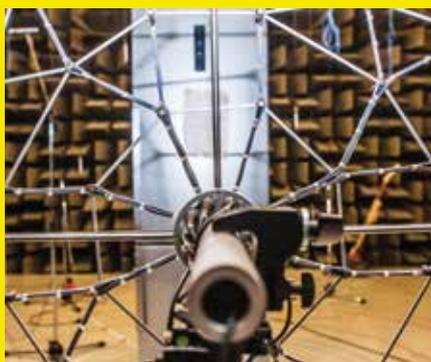
WMG shakes it up



Warwick Manufacturing Group (WMG), an academic department at the University of Warwick, is testing the robustness and lifespan of rechargeable batteries with the help of its new LDS V8 combo shaker.

WMG was founded to reinvigorate British manufacturing by providing research and education within engineering, manufacturing and technology industries, and, as part of the government-funded High Value Manufacturing (HVM) Catapult programme, is conducting research into low carbon mobility. The V8 systems are able to test large lithium-ion battery systems as they go through the cycling process. Soon WMG hopes to add thermal capability to the system for simultaneous vibration, cycling and temperature testing. ■

Gorenje improves its efficiency with acoustical array



Gorenje tests the sound power levels of a huge range of white goods in its anechoic chamber, including 1700 varieties of fridges alone. "To lead the field in an ever more competitive market, every 1/10th of a dB counts," says Head of Acoustics, Dr. Nikola Holeček.

Because speed and efficiency in measurement are so important in their business, Gorenje recently acquired an acoustic

array from Brüel & Kjær. By using array techniques like wideband holography, Gorenje has been able to greatly improve the productivity of their test chamber, and reduce costs. ■

Siemens to conduct large scale wind turbine testing



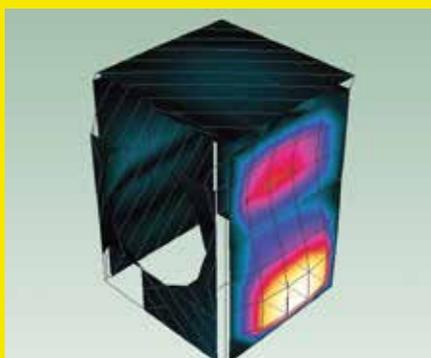
Siemens' goal is to provide wind energy solutions that meet both energy and environmental needs while driving down costs. To help achieve this goal, their engineers have been using PULSE to help develop their own in-house software to calculate sound power of large-scale wind turbines according to IEC 64100-11.

Siemens Canada purchased two PULSE systems last year to meet their growing

requirement to conduct sound power measurements on several large-scale wind turbine developments in Ontario.

The durability of the LAN-XI hardware and transducers make Siemens' job easier with their suitability for in-field measurements. The flexibility of the software helps Siemens to develop specific measurement applications. ■

Miele improves its testing capabilities



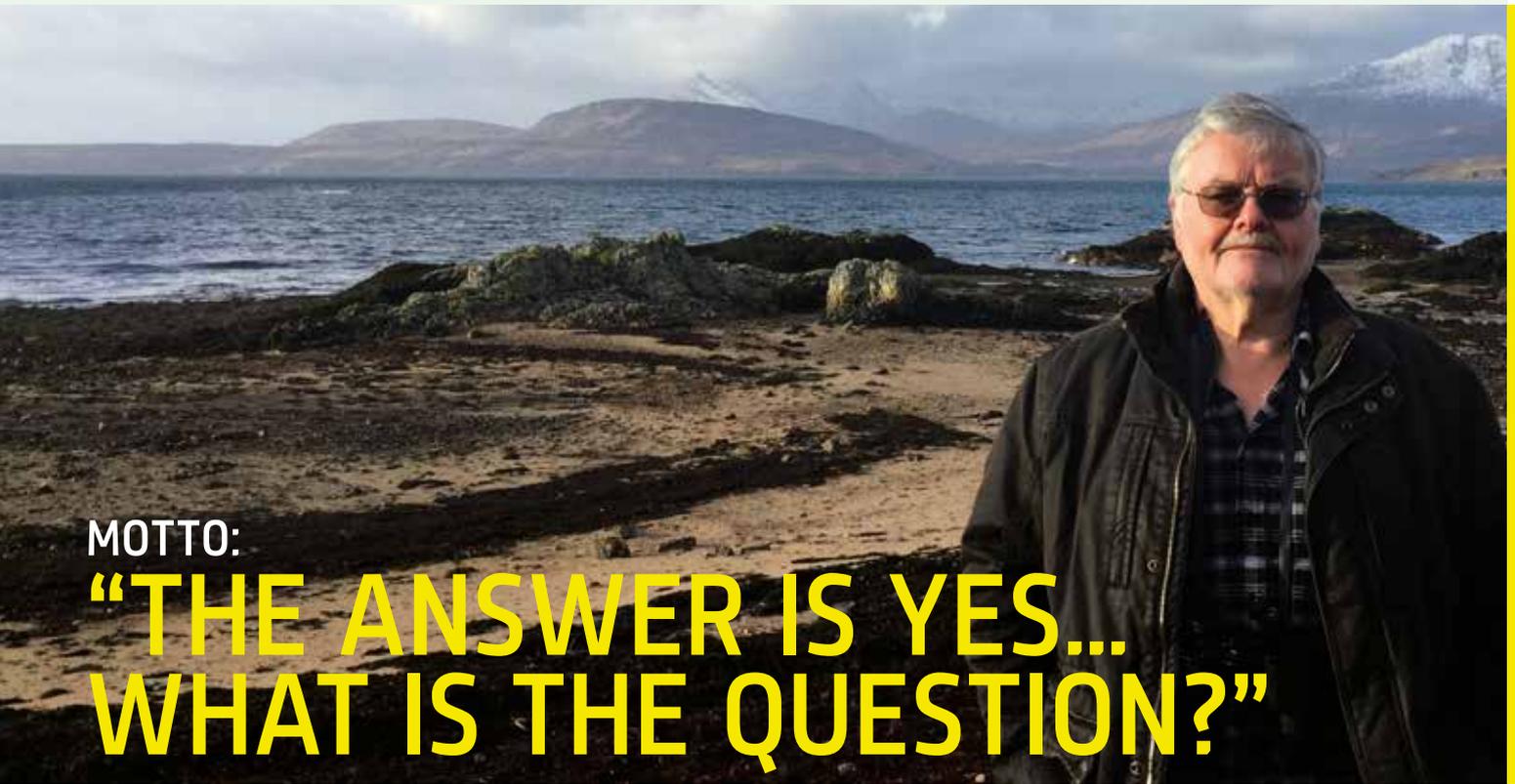
As the manufacturer of high-end household appliances ranging from dishwashers to vacuum cleaners, German company Miele is well known for the high quality and durability of their products.

Miele recently upgraded to a PULSE Reflex modal system together with Reflex Correlation and the ANSYS FE-Interface for their modal testing lab.

Senior R&D engineer, Mr Beckmann, is very excited about the new system, citing the user-friendly graphic interface and the new measuring possibilities available with the correlation tools. Dr Klamt, department manager of the R&D lab, finds the system improves their productivity in their daily modal analysis tasks. ■

FIVE QUESTIONS FOR ROGER

65-year old [Roger Williams](#) spent most of his childhood in Llanfairpwllgwyngyll-gogerychwyrndrobwllllantysiliogogoch, North Wales. Today, Roger is a Senior Application Specialist at Brüel & Kjær, where he is transferring 45 years of consulting, development and practical experience into new NVH tools and solutions.



MOTTO:

**“THE ANSWER IS YES...
WHAT IS THE QUESTION?”**

What is the most challenging project you have been involved in?

Turning the NVH Simulator from a research project into an industry-accepted product development solution. And I look forward to showing the new products and solutions we are developing to potential customers and getting their reaction.

What is the best advice you've been given?

There is a well-known expression: “Energy flows where thoughts go” – so think positively and your energy will make good things happen. This philosophy has helped me in my personal and work life.

What irritates you most about your own personality?

I wish I was less of a control freak!

If you could invite three famous people to dinner, who would they be?

Jamie Oliver because he is opinionated and a great cook, Stephen Hawking because he is brilliant and has a great sense of humour, and Lewis Hamilton because he is a local boy and is cool.

What are your hobbies?

Music, cider (making and drinking), walking in the countryside, home improvements, my Honda Civic Type R and my house on the Isle of Skye, Scotland.

