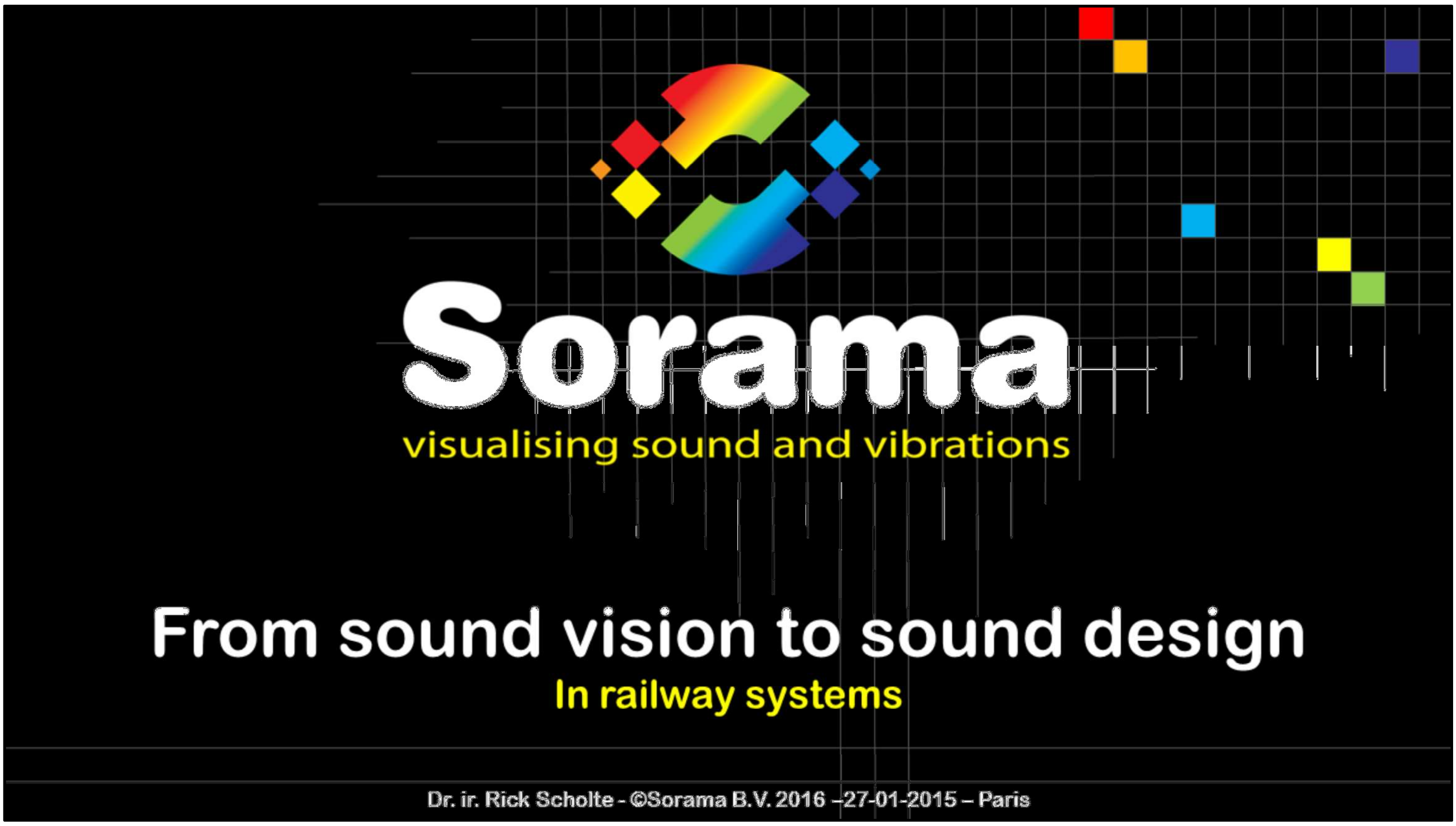
Sorama

visualising sound and vibrations



Abstract

From sound vision to sound design in railway systems

Noise and vibration pollution from railway systems is a big environmental issue with great impact on society. In other to deal with this issue a profound knowledge and understanding is required of perception by the receiver, the behavior of the source and the path in between. Acoustic camera technology is able to provide the required knowledge and insights, whereas new developments enable largescale, cost effective and powerful applications.

Eindhoven University of Technology

Sorama, a spinoff company of the Eindhoven University of Technology in The Netherlands, developed a Guinness World Record breaking MEMS microphone array technology alongside powerful near and farfield acoustic visualization and 3D calculation methods. These acoustic cameras are already widely used in all areas of industry, tackling noise and vibration issues on a much larger scale and far lower threshold than previously possible.

This presentation focuses on the possibilities of temporal as well as continuous far and nearfield acoustic observation in railway systems and the coupling to obtaining new solutions and insights that were previously impossible to obtain. Also, technical background of distributed, synchronized acoustic cameras and inverse acoustic methods are provided. The goal is to provide a clear understanding of the possibilities and knowledge that is currently available in the field of inverse acoustics. This enables us to find sound railway system designs originating from sound vision.

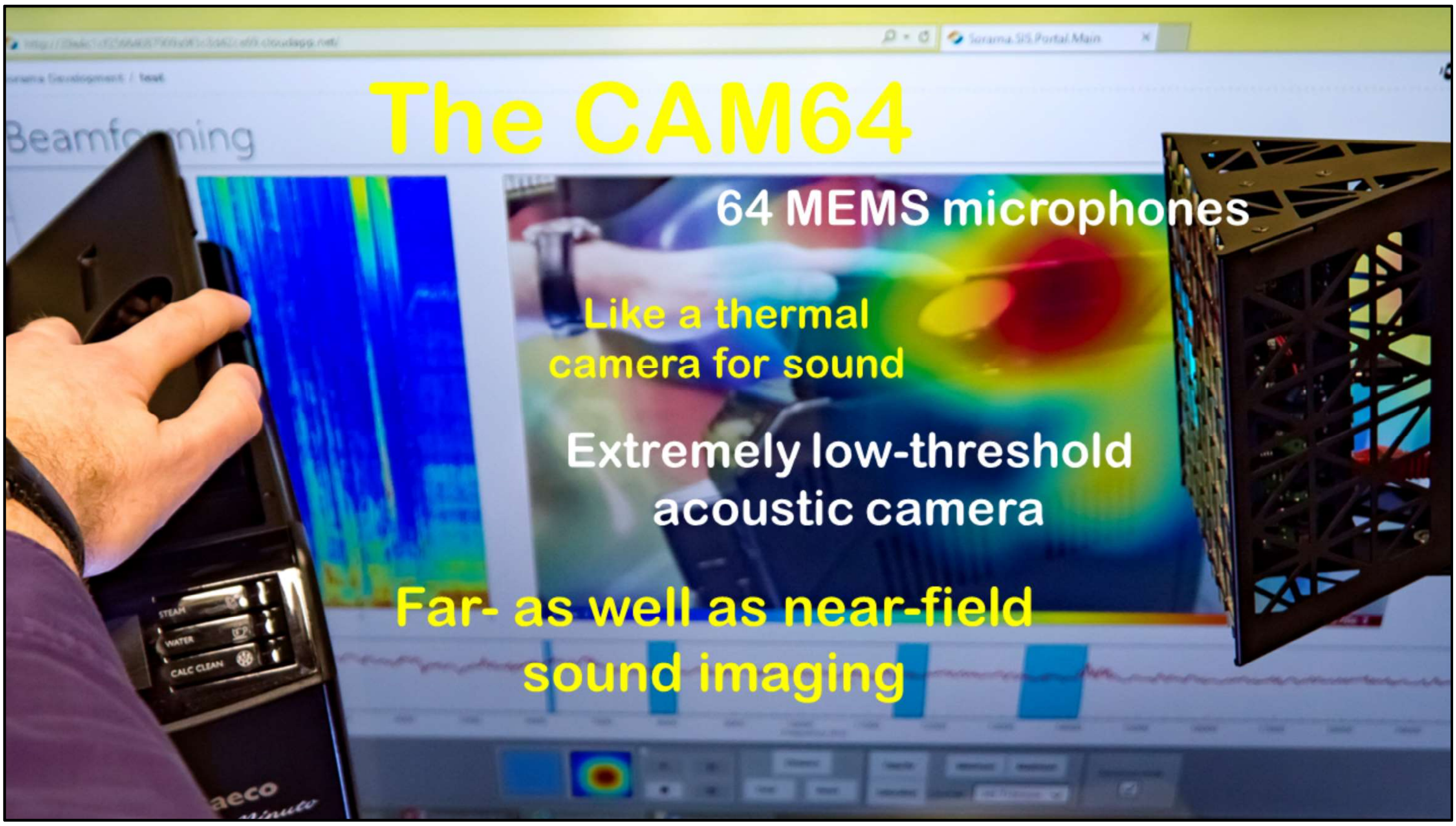
Intro Sorama: “Sorama is a spin-off of the Technical University of Eindhoven in 2009. Its name is formed by two Greek words ‘sonos’ and ‘orama’, freely translated ‘sound vision’. Sorama is literally looking at sound and providing insights and understanding, but we also have a vision on how to deal with sound...”

[Sound/noise plays during slide]

“Sound affects us in many ways; it can be pleasant (music, performace) or functional. Sometimes it can be annoying and quite often, especially in modern day life in the big city, it can be unhealthy (amongst other things we produce higher amounts of stress hormones when noise increases in level). ”

“The WHO reported in the last couple of years that in Europe alone, more than 1 million healthy life years per year are lost due to noise pollution caused by traffic. After air pollution it is estimated that noise pollution is in second place for most damaging environmental influences.”

“Sorama’s sound vision: to make the World sound right. Not only reduce noise, but also play a role in de sound design of our products and environments (we spend much time and effort on visual design, but how do we want our products to sound?)”



“It is nice to have a vision, but what can we [Sorama] offer to make a difference?”

“The CAM64; an extremely low-threshold and obtainable acoustic camera – like a thermal camera but now for sound – which combines an optical camera with 64 digital MEMS microphones (like the ones in your smartphone);

it can be easily used on a large distance meters to multiple hundreds of meters for source detection and very close-by to investigate micro vibrations and dynamical behaviour in structures, for example.”

> Next slide is an introduction video to the CAM64.

Video shows the CAM64 hand-held acoustic camera in action; both in stremaing far- as well as near-field mode; the far-field mode lets you easily see where the noise of the coffee machine in a certain stage is originating from, also the near-field vibrations of a tuning-fork are shown about 1500 times slower than real-time; when you put the tuning fork to an aluminum plate the mode shapes of the vibrations at a certain frequency are shown.

Customer success: ResQtec from The Netherlands; an OEM in rescue equipment.

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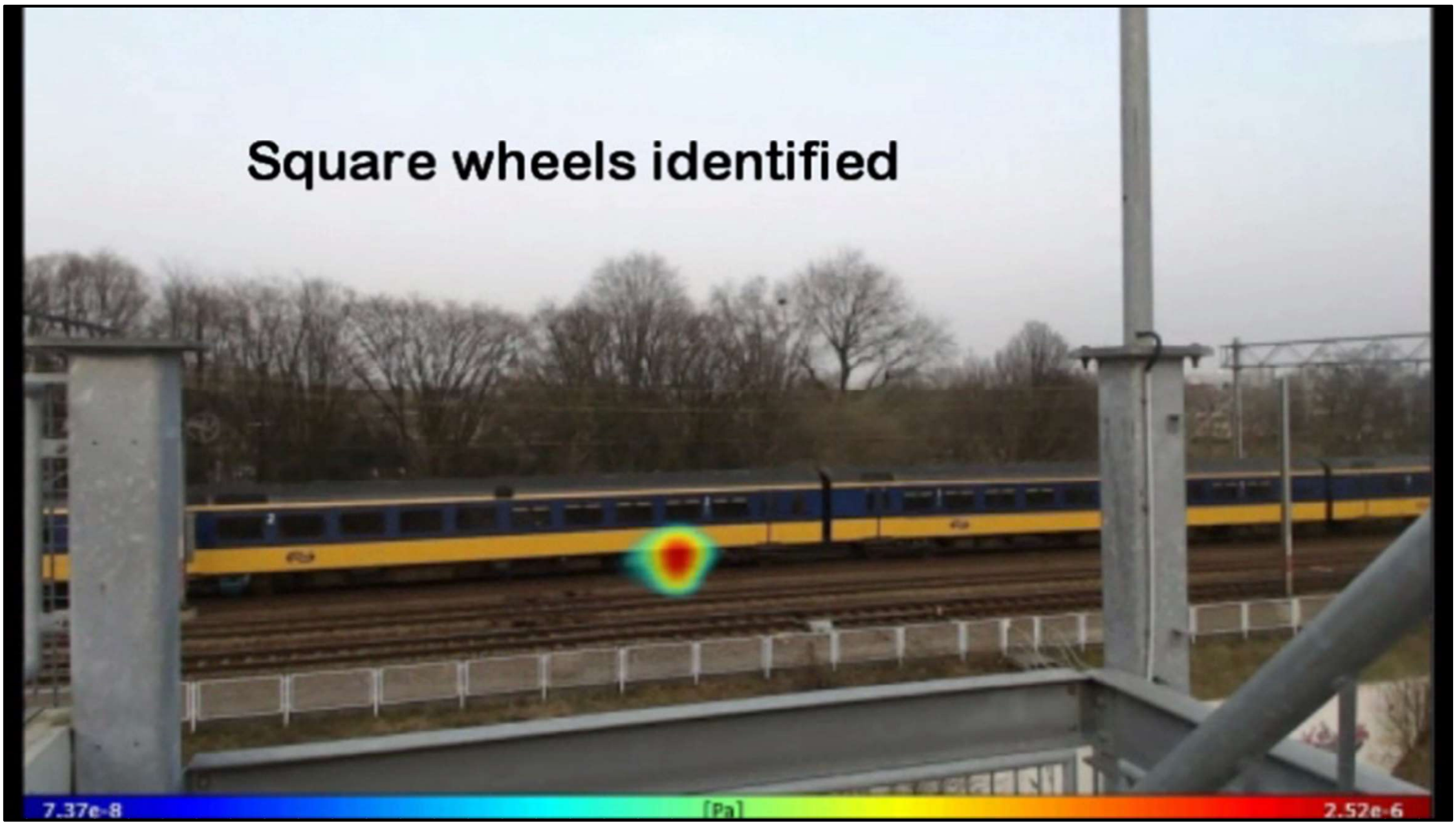
Sorama
visualising sound and vibrations
Sorama
Hessel Vink:
Product Manager Resqtec
“Using the Sorama Cam early
in the development cycle made us
focus on the most important issues”
9


Hessel Vink:
Product Manager Resqtec
“For Resqtec it is a huge step to be quieter with an open unit than the competitor’s unit with sound enclosure.
Thanks to Sorama”
Sorama
Sorama

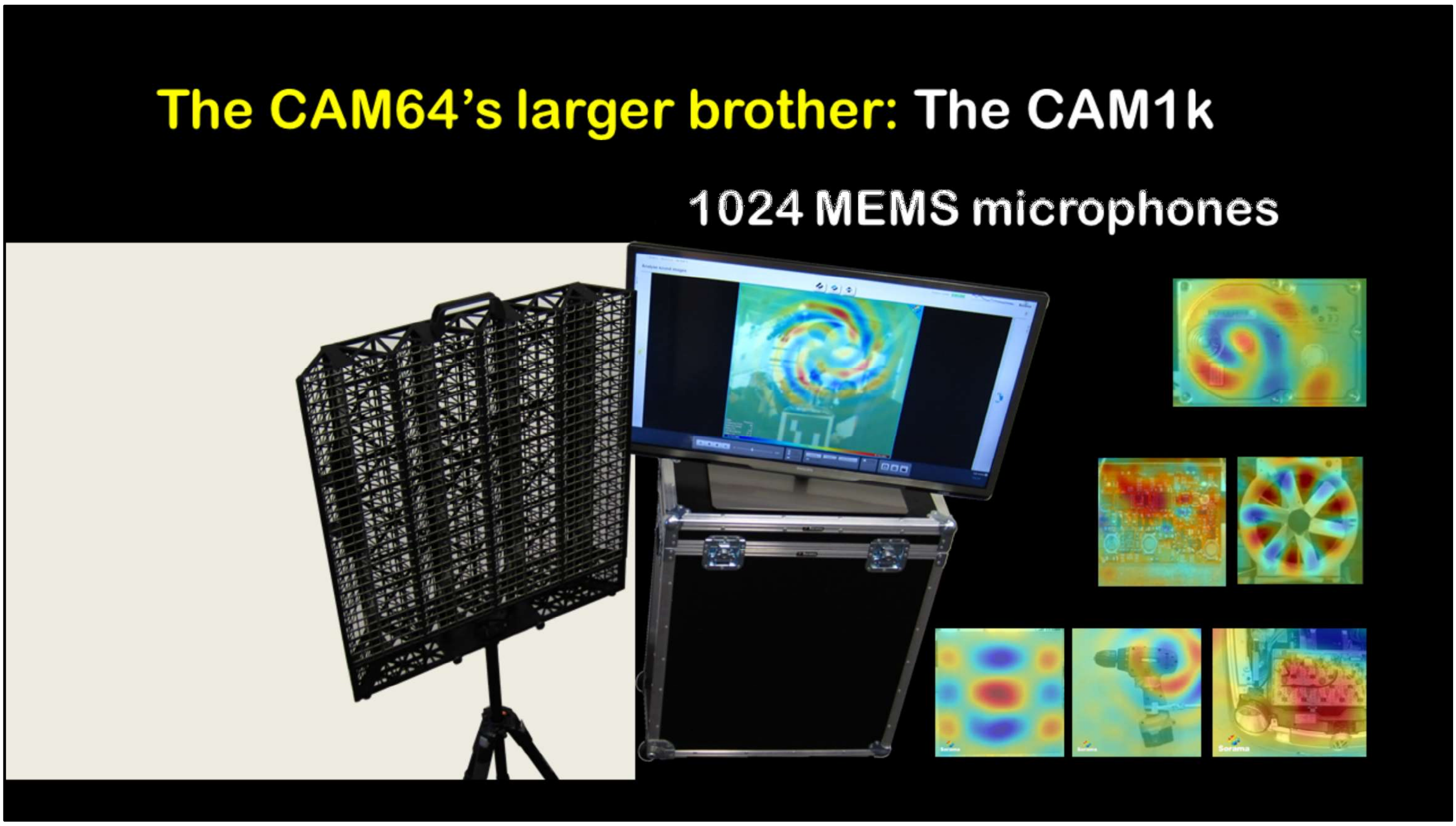


“We now move from the near-field to the far-field; This video (about 2 mins) shows far-field acoustic visualisation of passing trains at about 70-100 meters in Eindhoven, The Netherlands. It was measured with the CAM1k the 16 times lareg array than the CAM64.”

“The setup took 2 minutes to fully set up and start measurements and analyses on-site”

“A few of the source identifications are shown in the video; this far-field technology can be combined with synchronised near-field measurements with other sound cameras (arrays) near the tracks”

> Next slide: digital MEMS microphone, placing it in a larger array and introducing the CAM1k sound camera.

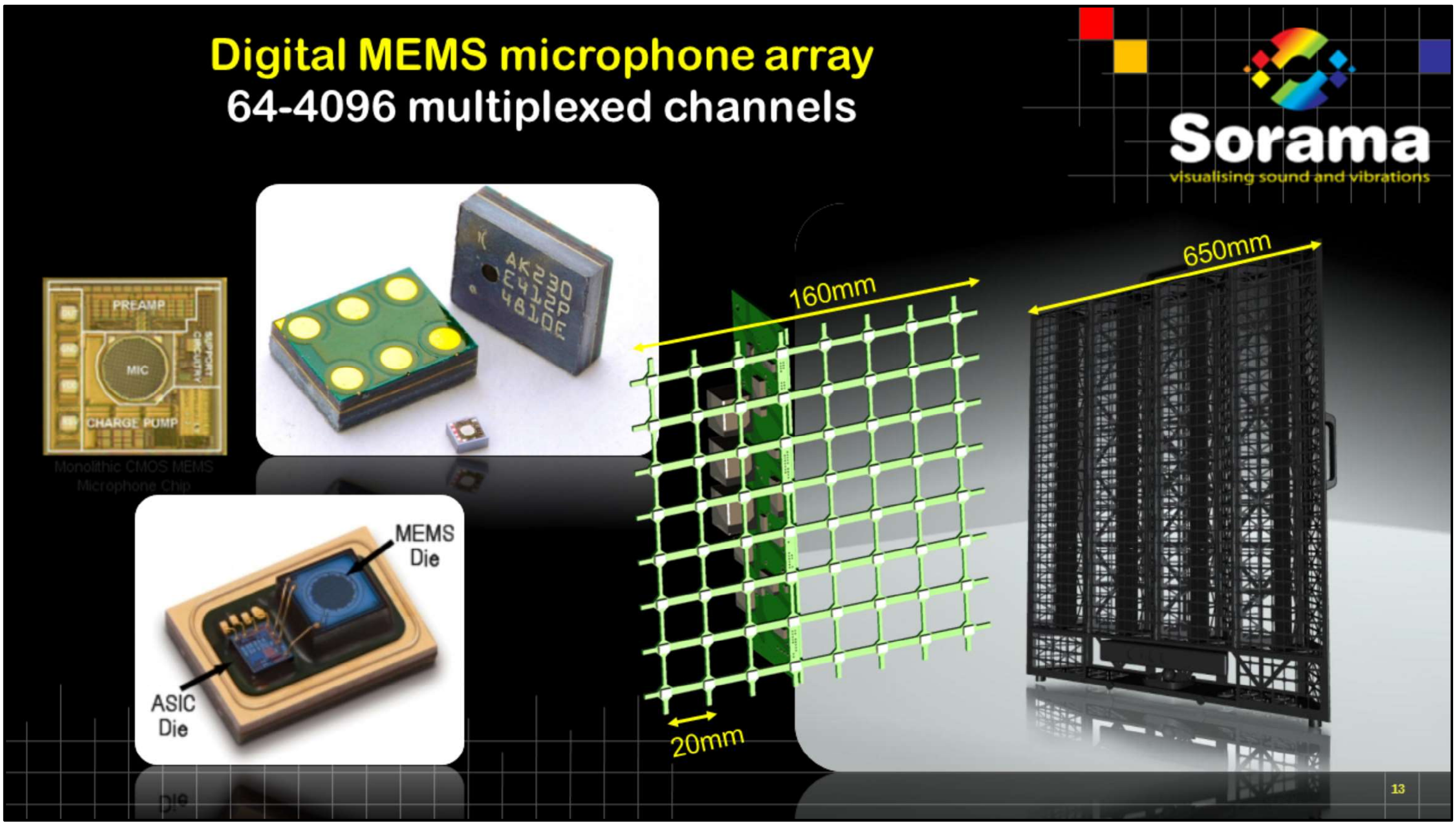


First view: “This is a digital MEMS microphone, like the one in your smartphone”

[Click]: “To benefit from multiple sensors and the spatial (positional) domain we decided to place multiple sensors directly on a printed circuit board including al required electronics for data acquisition. This means the microphone array can be produced in a standard electronics production process, making it possible to scale-up the amount of sensors and/or arrays dramatically at much lower costs.”

[Click]: “This resulted in the introduction of the Sorama CAM1k, a 1024 microphone channel acoustic camera”

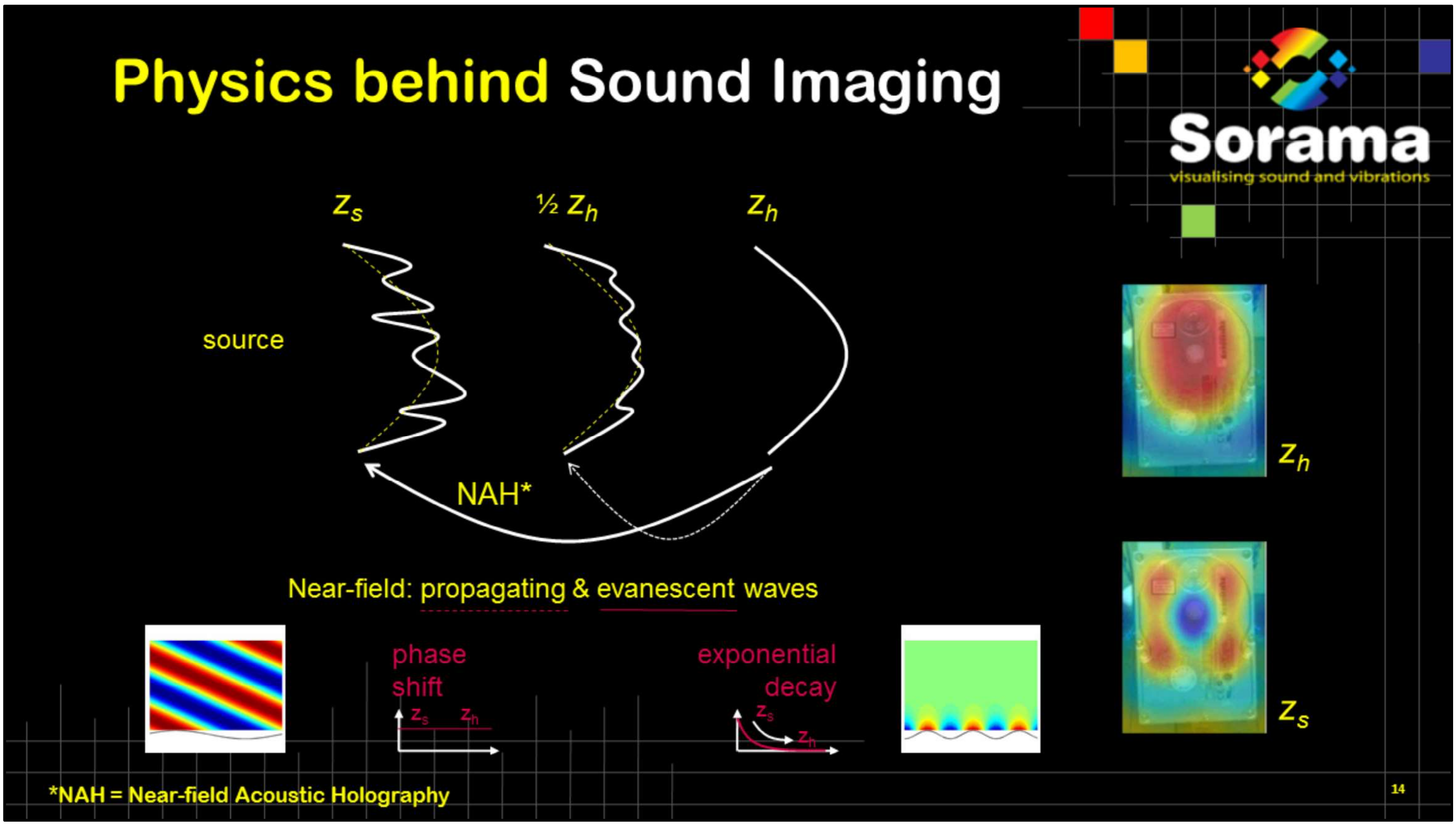
Next: more details on the MEMS microphone and array setup (can skip if time is short)



“Here you see the digital MEMS microphone in close-up; the microphones are produced in a chip-making process and completely made out of silicon (from the wafer). [click]”

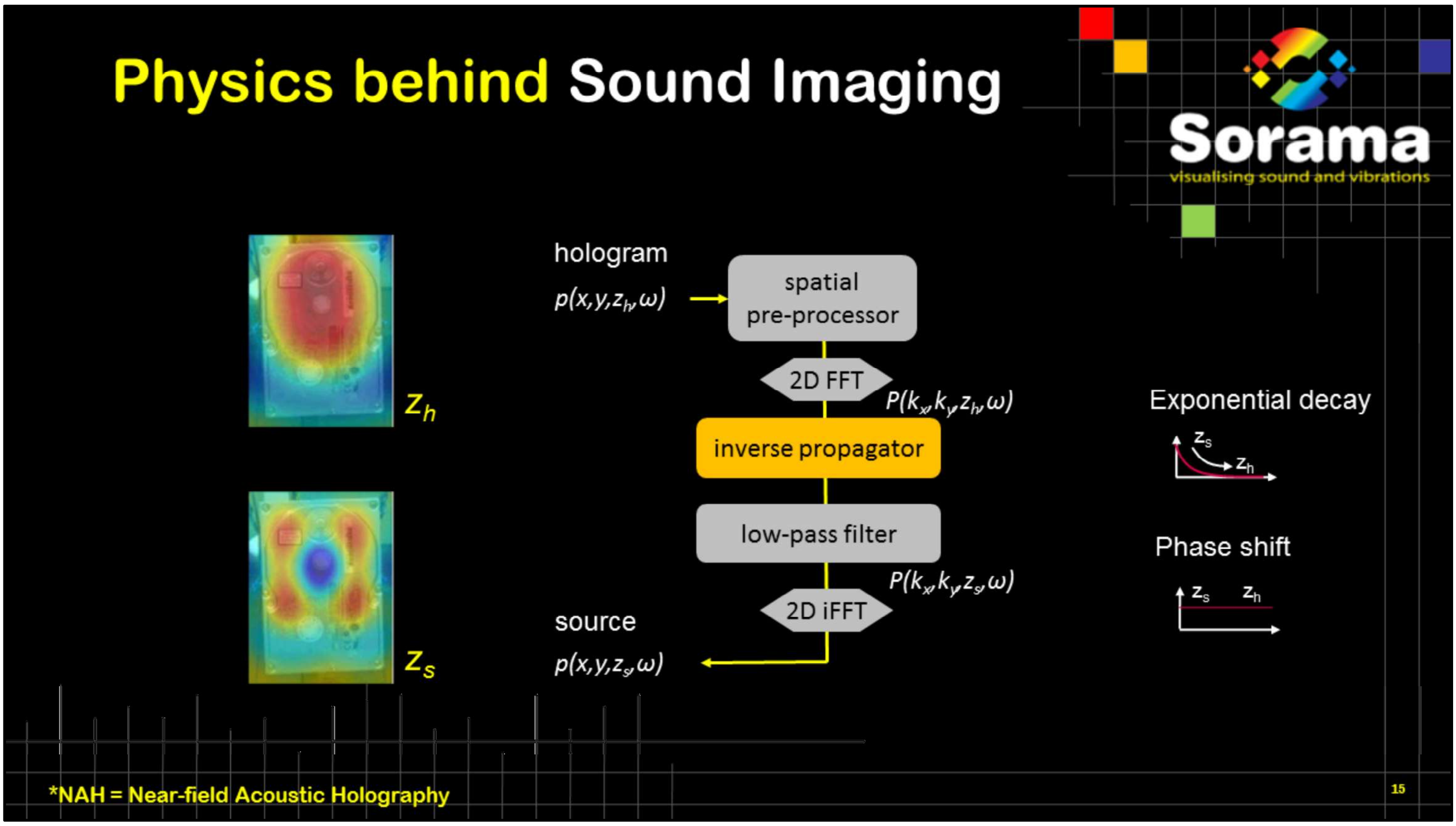
“The standard microhpne array modules measure 16 by 16 centimeters and for the CAM1k they are placed 4 by 4.”

> Next slide: theory, physics behind (near-field) sound imaging



"Near-field sound imaging makes use of both propagating as well as evanescent waves; The source of sound often contains both, while at larger distances from the source only propagating waves remain."

"With a technique called Near-field Acoustic Holography we calculate the inverse solution of the acoustic wave equation; which means that we use the sound measurements from our MEMS microphone array at a distance z_h to determine what happened at the source at distance z_s – the harddisk drive example shows a point source at a few centimeters distance, while at the surface the vibrations look very much different. It would also require different means to tackle the noise."



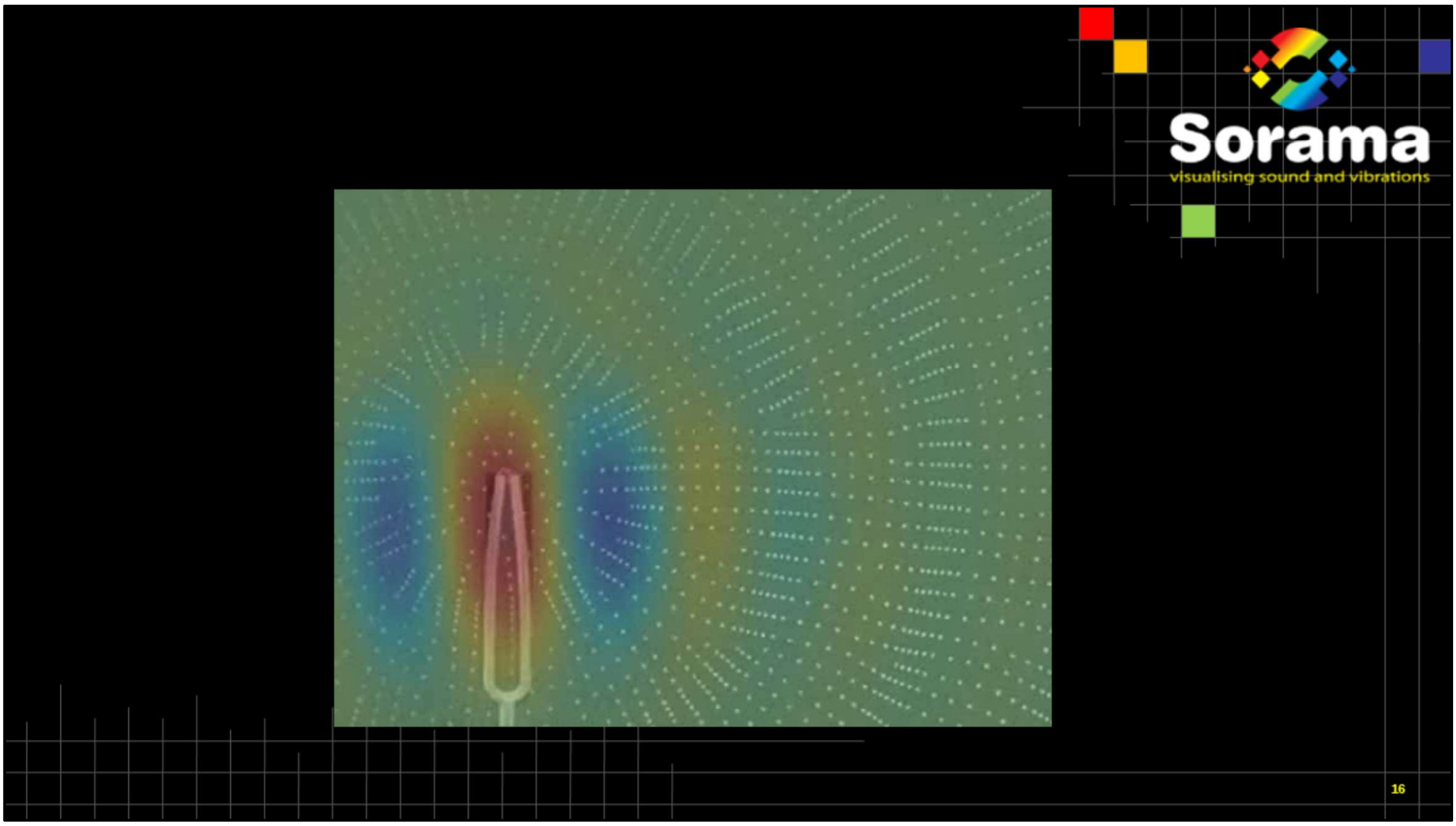
“Here the processing steps are shown to determine the inverse near-field solution of the sound source”

“It requires advanced filtering methods and fast Fourier processing”

“From the measurement of sound pressures we are ale to determine particle velocities in 3D and sound intensities too; in fact you know everything there is to know about a sound source in a certain direction.”

“Also, compared to the far-field imaging method, near-field acoustic holography image resolution is not bounded by (lower) frequencies – even on freuqncies as low as 1-20 Hz we have seen spatial details of a few centimeters.”

> Next: example with a tuning fork showing the near-field effect and radiation efficiency.



“Here we see the slow motion view of the vibration of a tuning fork in A (440 Hz)”

“When you hit a tuning fork and hold it in free air you can hardly hear it; while in the near-field it shows that there are high vibrations around the fork.”

“440 Hz vibrations in air under normal circumstances have a wave length of about 75 centimeters; when the fork moves inward the middle contains an increased amount of air particles (high pressure, so the sound image becomes red), he side-lobes are blue (indicating low sound pressure)”

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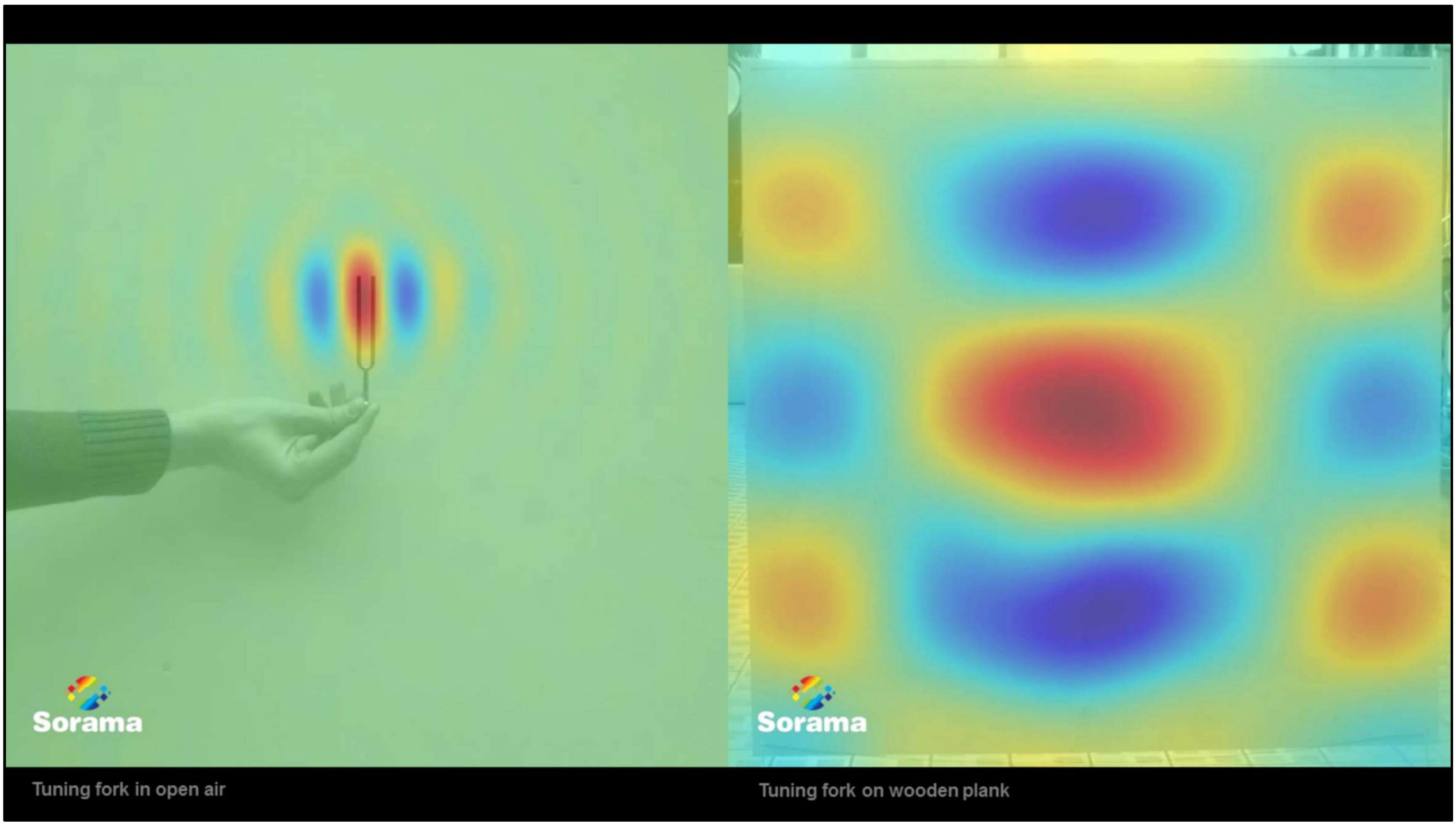
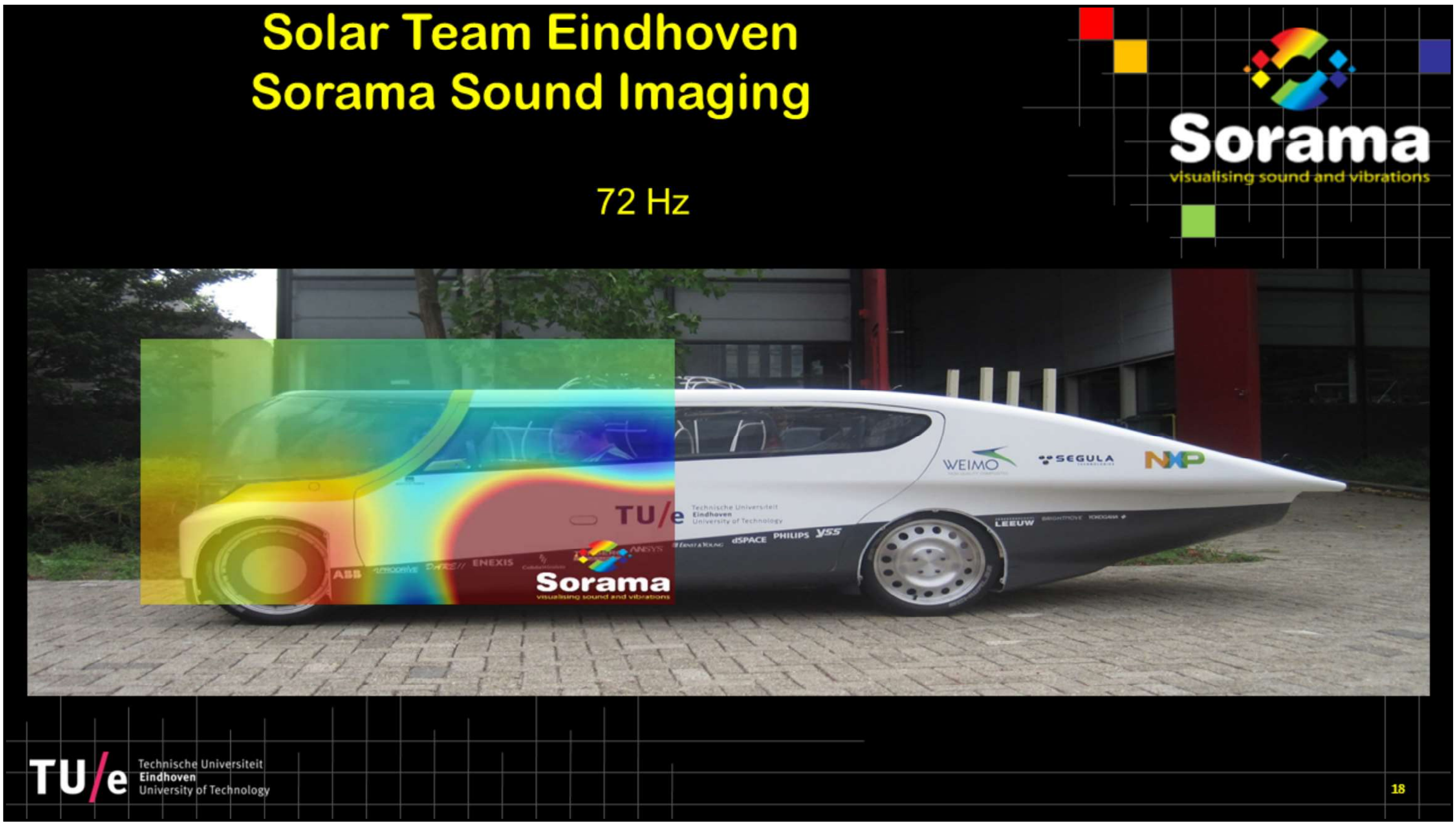


“when the distance between high and low pressure areas is much smaller (in this case only a centimeter or two) than the wavelength in air, we call the vibration evanescent since it will degrade with an exponential power; hence, we wont hear it at a distance”

“mount it on a wooden plank and the acoustic energy flows – look at the vibrations of the board – the 440Hz hits a resonance in the wooden plank. Now the distances between maximum and minimum pressures are much longer. In this case it will cause mostly propagating waves and you will hear the tone at a much larger distance.”

“This also happens in vehicles like trains and cars – an electromotor for example will have good noise specs in itself, but mounted in the complete system it may excite resonances in other parts of the system.”

> Example wth solar car on a roller bench in next slide



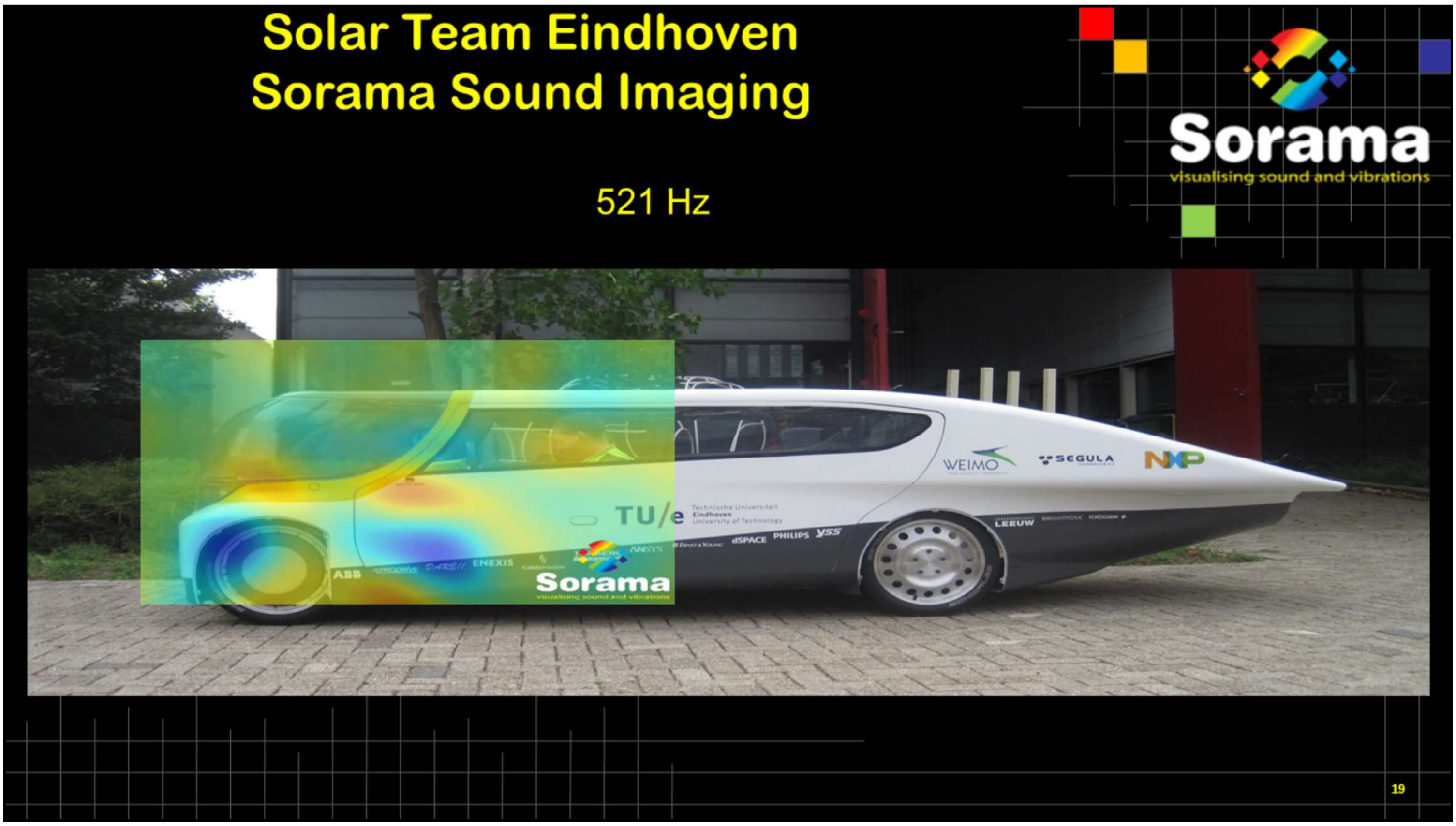
“This example shows the family solar car of the Technical University of Eindhoven, which won the World Solar Challenge in Australia two times in a row now”

“At a few dominant frequencies the vehicle shows extreme vibrations and noise radiation. By using a measurement in the near-field of more than 6000 microphone positions we made these sound images.”

“The vehicle has an in-wheel electric motor at the front and was driving on a roller bench in the lab (we used a nicer picture as background)”

“At a low frequency of 72 Hz we see vibrations (resonance) of the door, yet they are introduced by instability in the driving axis in front”

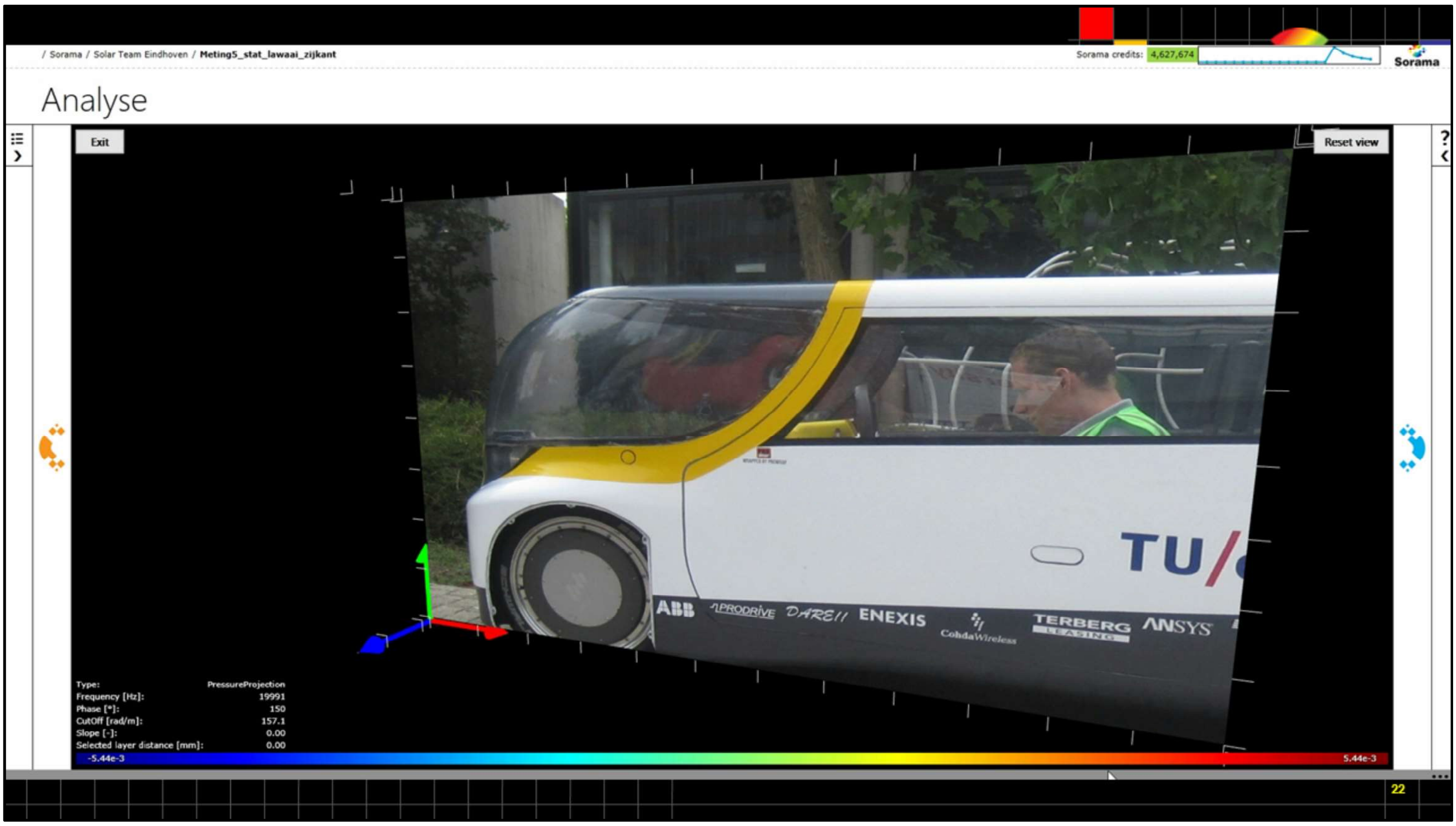
> Next slide: other dominant, somewhat higher frequency.



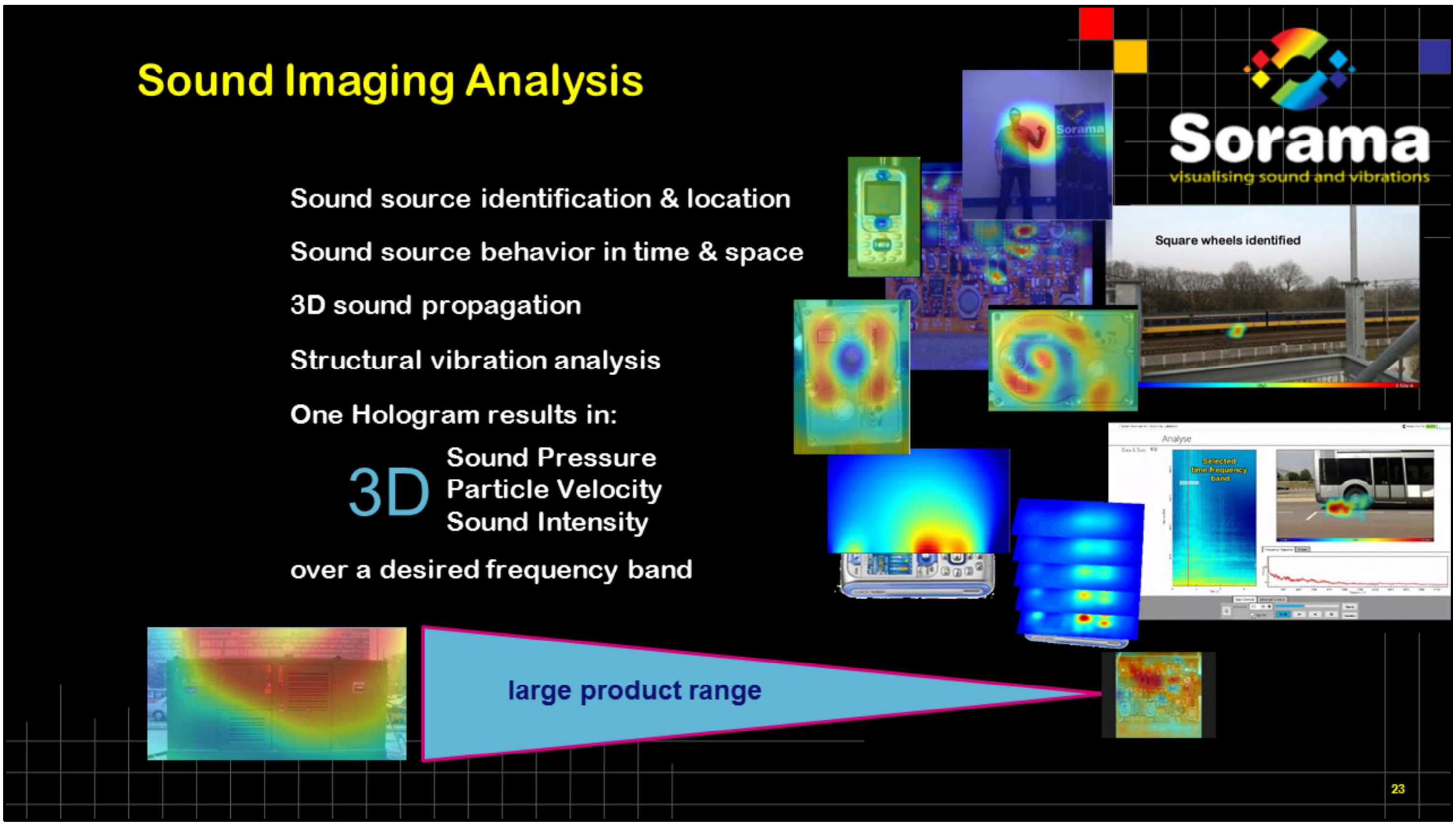
"At a somewhat higher frequency above 500 Hz we see an unbalance in the front wheel causing parts of the door and window to resonate."

"A third major contribution to the noise radiation sits at 4 kHz; you can see a clear 'umbrella' mode in the wheel cover."

“Noise radiation at very high frequencies originate from the in-wheel electrical motor – in this case you can count the magnetic poles of the coils”



“Besides 2D sound images the Sorama platform also enable 3D sound propagation from near- into far-field. This way you can determine under which angles noise propagated outward and/or how efficiently a certain vibration actually rediates outward.”



"This is a recap of the possibilities of sound vision technologies for rail (and other) dynamic systems"

“Sorama’s sound vision: observe before you act, gain insight into the dynamics, understand what’s happening and act accordingly to achieve an improvement design.”

Statement to think about

[Click] to last slide

“Sorama’s Sound Vision Makes the World Sound Right”