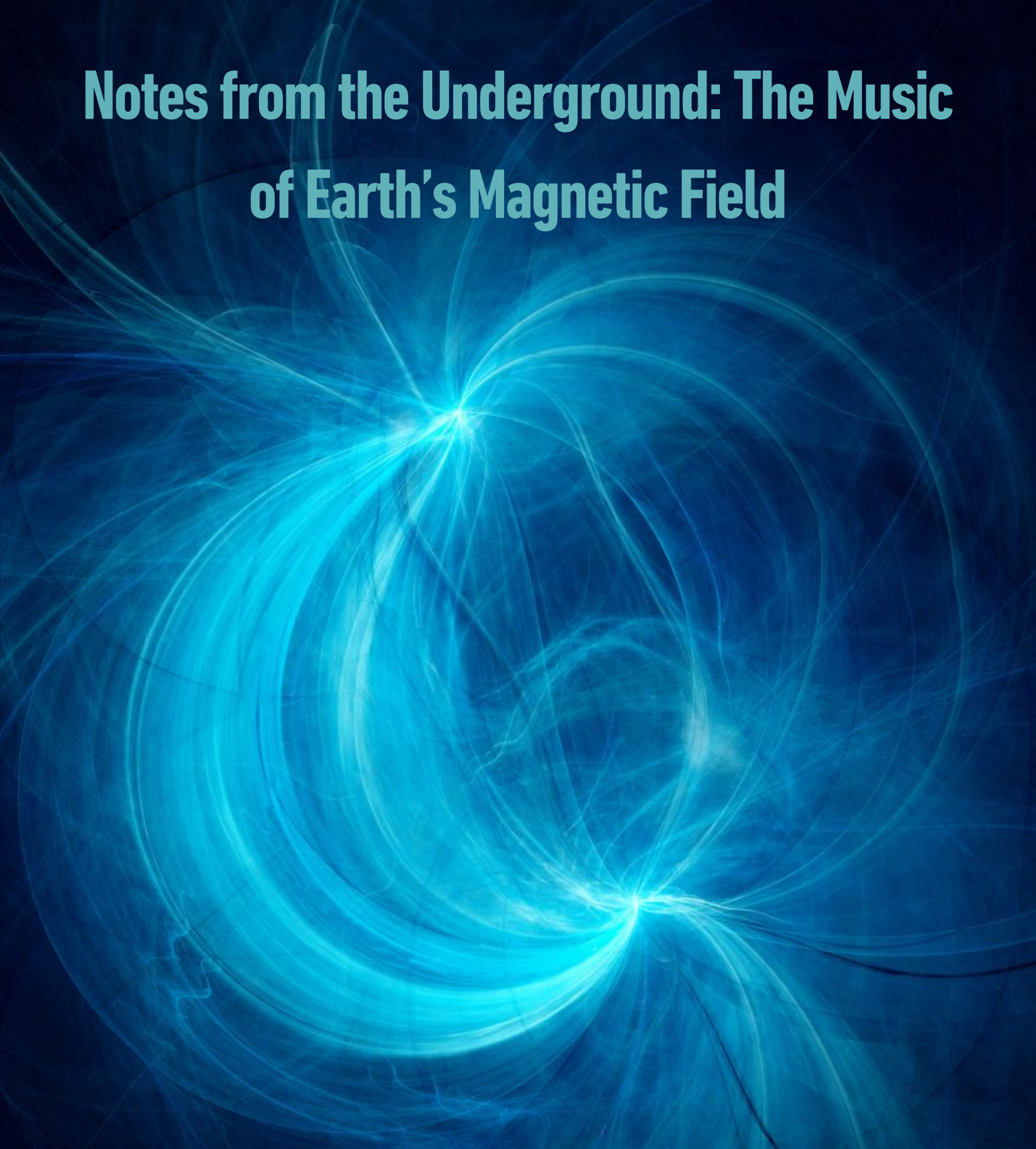
Notes from the Underground: The Music of Earth's Magnetic Field



An Interview with Klaus Nielsen, Musician and Project Manager at the Technical University of Denmark

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"Sound of Earth's Magnetic Field: An Audio Installation using Sonification for Accessibility in Space Sciences" on display at the rotunda at the Vienna International Centre during the 66th session of the Committee on Peaceful Uses of Outer Space (COPUOS) from 31 May to 9 June 2023.
Credit: Wenbin Zhang

Cover Image Credit: Shutterstock

Introduction

Klaus Nielsen is a Danish musician who currently wears two hats, producing music independently and working as a Project Coordinator for the Department of Space Research and Technology, Geomagnetism and Geospace Division, at the Technical University of Denmark (DTU). After a long career in literary science, he was inspired to transfer to his current position, where he was excited to apply his experience in the arts to the space sector.

One of his latest projects, in collaboration with Nikolai Linden-Vörnle (aka KamikazeVildsvin) and Clemens Kloss (scientist in the loop), Nielsen used data from ESA's Swarm satellites to create an artistic auditory representation of Earth's magnetic field. The project garnered widespread news coverage and was first exhibited at the Solbjerg Square in Denmark and on ESA's SoundCloud, where it has amassed over one million plays. From 31 May to 9 June 2023, it was also displayed at the Vienna International Centre, home of the United Nations Office of Outer Space Affairs, during the 66th session of the Committee on Peaceful Uses of Outer Space (COPUOS). Using a multi-channel speaker system, the audio conveys changes in Earth's magnetic field over the past 100,000 years as well as spatial variations in the strength of the magnetic field. Speakers embedded in the ground project sound upwards, mirroring the direction of the magnetic field, which is generated primarily in the Earth's core and protects the planet from harmful solar radiation.

In this interview, Nielsen discusses the inspiration behind his project, the technical work that went into converting satellite data to audio, the institutional difficulties sonification projects face, and future directions which sonification may take. Between mentions of turtle sounds hidden in the final audio and the difficulty of outreach through SoundCloud, an overwhelming message emerges: data and sound are inextricably linked, and artistic sonification projects can bring awareness to this magnificent connection. His project, intended primarily as an outreach tool and work of art, uses the same principles as other sonification projects which aim to enhance research through presenting data in a new manner and make the space sciences more accessible for persons with disabilities, particularly individuals who are blind or visually impaired.

> *[D]ata and sound go together; sound can be another way of representing data.*

Can you start by just telling me a bit about yourself and your path up to this point?

I have a PhD in literary scholarship, which is usually very distant from space. I worked for quite a while as the chief editor for a major publication project, and then I needed a change of scene. I always liked space, so I got in contact with the space division at the Technical University of Denmark, and we came upon the idea that an arts major can also do important work in space. Of course, I don't do space science. I'm exclusively administrative, but it's good fun.

That's how I ended up in space, and I'm now at the division of geomagnetism working 100% on one particular project that we do, together with ESA, which is their Swarm constellation, and that's 3 satellites orbiting Earth measuring its magnetic field. It's been there for almost 10 years now, so it's an old mission, but it's still bringing down valuable data, so ESA is keeping it running. At the Technical University of Denmark, we make sure that the data coming down is exploited in the best possible ways.

Once you got in contact with the University, how did you hear about and become involved with sonification?

I believe the first time I laid ears on sonification was when I saw Jody Foster in Contact in '97, because that's when it dawned on me that data and sound go together; sound can be another way of representing data. I always thought it would be cool to do something with data, and in the past 20 years or so, there's been quite a bit of a development within sonification. I haven't followed it very closely, but it became obvious that something could be done when I was discussing the subject with colleagues at the University. For me, thinking in sound all the time, and for them, working with data and talking about these time series of movements in data, it became quite clear that we could do something fun with this.

A speaker well from the original setting of the installation in Copenhagen. Credit: Eduardo Lima Simões da Silva

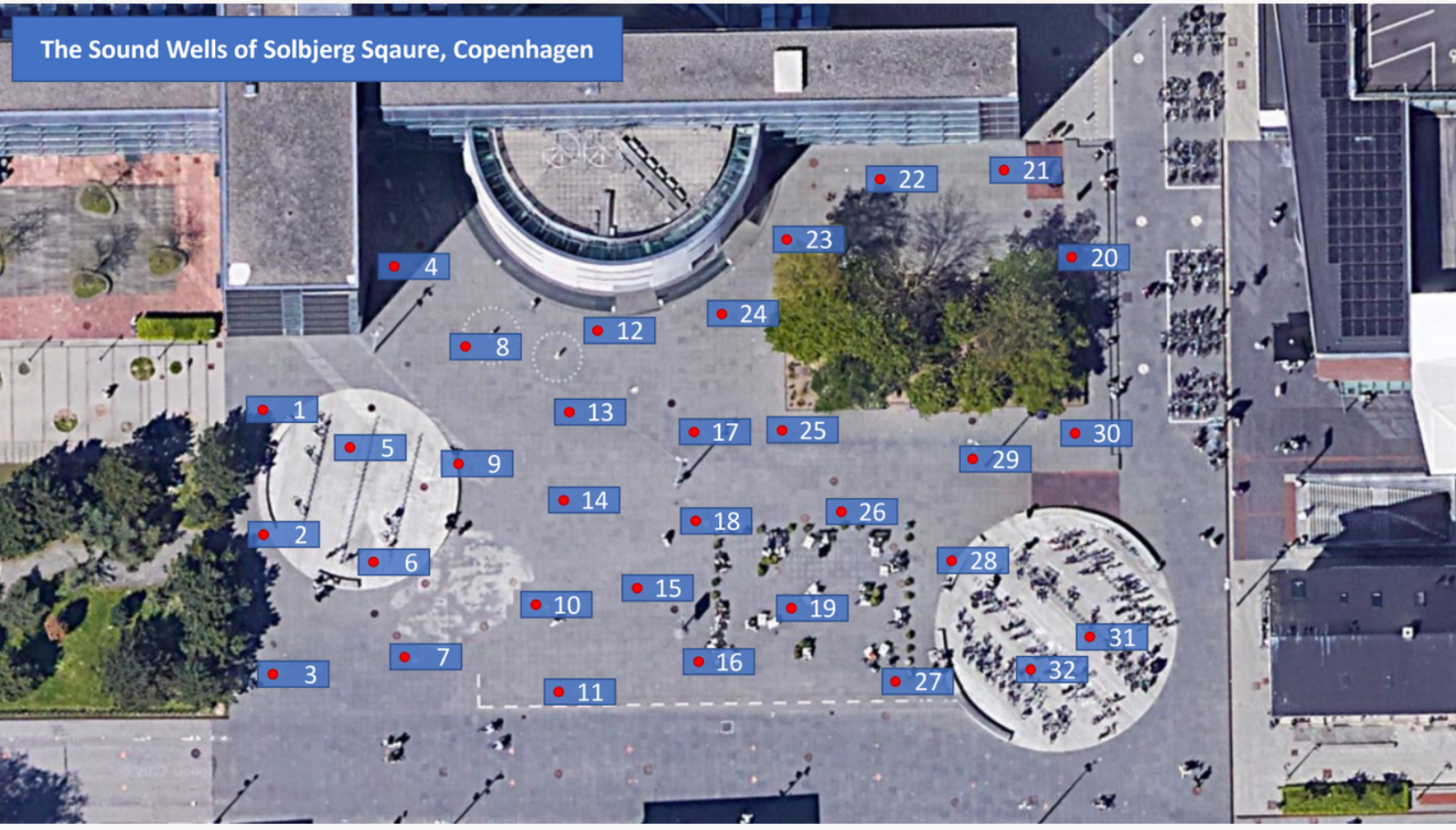
Why did you choose to work specifically with data from Earth's magnetic field?

The magnetic field is very cool, especially the core field, which is the main contribution to the magnetic field. Of course, there's all kinds of different parameters that these satellites are measuring, but there's something very intriguing about the core field which is generated deep within the planet. There's also a weird inherent connection between magnetism and the way speakers produce sound.

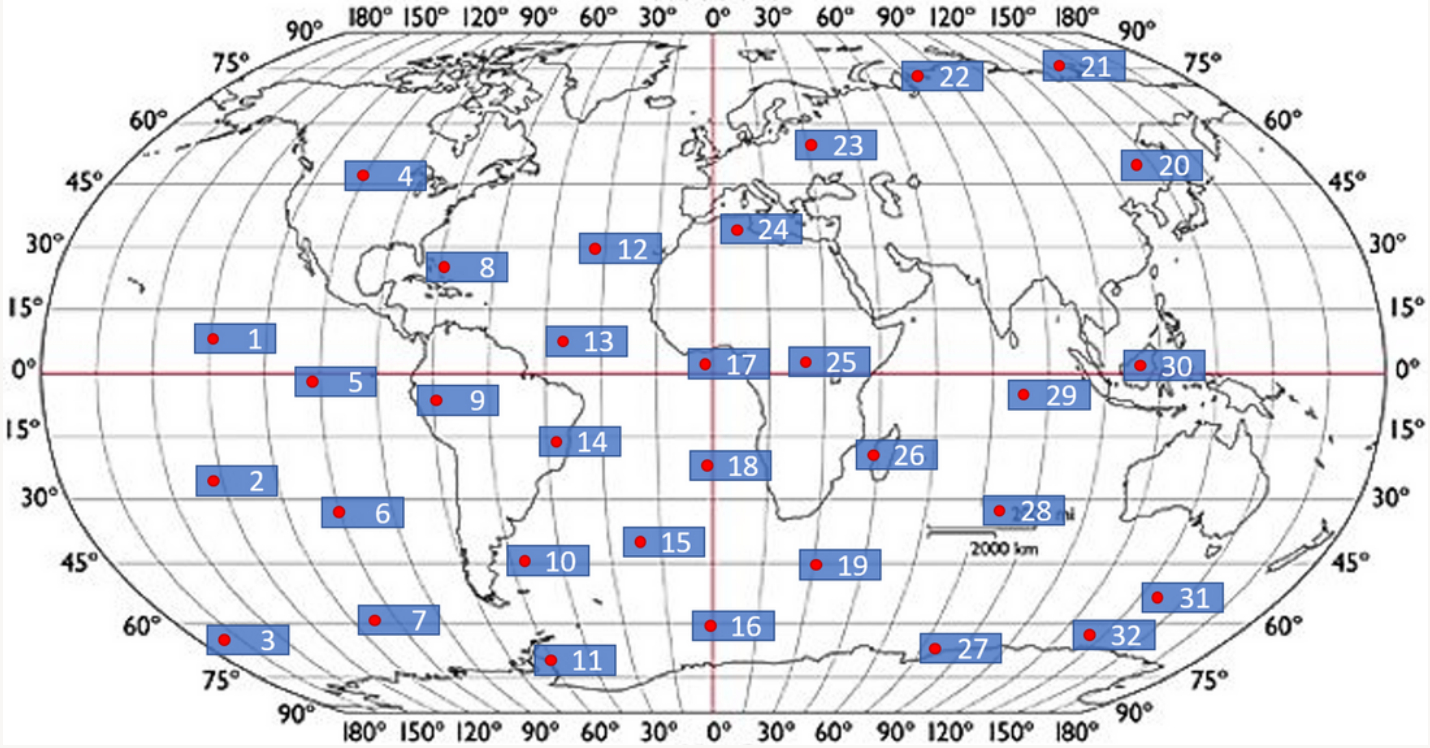
The core field is generated by an ocean of liquid iron 3,000 km below our feet that flows around in currents, and that's what generates the magnetic field, which extends far out into space and protects us from harmful radiation and charged particles from the sun. There are all kinds of unknowns in this process which make it very intriguing.

The original idea for this project came about from a really weird public square in Denmark, Solbjerg Square, that has speakers built into the ground. 32 speakers have been placed over roughly 15,000 square meters and are covered by what look like wells for rainwater. It has 32 channels, so you can decide what comes out of each speaker individually. I was listening to a work produced for this sound system, walking around on this square, and having a totally immersive experience, with different sounds coming from all around me.

That give me the idea that we have the magnetic field protruding from Earth and shooting out into space, protecting us from the Sun's particles, the same way we have this sound coming out of the ground. If we could represent the magnetic field as sound, there would be this cool connection between the direction of the magnetic field and the direction of the sound. That was how we decided upon the core magnetic field instead of other contributions to the magnetic field. Very high in the upper atmosphere there are also some things that contribute to the magnetic field, but it seemed like the most appropriate route to go with this core field.



The distribution of speakers in Solbjerg square in Denmark, where each number is a different speaker. Credit: Klaus Nielsen



The magnetic field measurement location to which each speaker at Solbjerg corresponded. Credit: Klaus Nielsen

You're an artist and a musician. To what extent did this feel like an act of artistry for its own sake versus an outreach project to engage the public and help them understand Earth's magnetic field? Are those two concepts inherently linked?

One of the tasks in our contract with ESA is to do outreach about the Swarm satellites and the subject of Earth's magnetic field. Opportunities to do so are not so easy to find, so we spotted this opportunity and welcomed the chance to use it. For me it also meant that I could bring my artistic side with me to work – which I have to admit was a very good feeling. So, in a sense this was a commissioned work of art, but I went at it with the same creative playfulness as I do with pieces that do not have a fixed end goal. It was a lot of fun.

It did turn out to be quite a success in the sense of an outreach project, though. We hadn't anticipated the success of the project, so that was super cool. We had that event at the square in Denmark, where we had 32 channels, and it ran for a week, but the largest response we got was when ESA posted it on their SoundCloud and it eventually got around a million listens. I mean, I would love to have some of my music get a million listens on Soundcloud. It hasn't happened yet. That's when the international media picked up on the story and UNOOSA reached out to us for inclusion in their report on sonification and the event here in Vienna. It became quite clear from that this is something that people could use as an outreach project.

The children from kindergarten are fascinated by the sounds of rocks and water. They wave their hands and sway to the sounds.
- Exhibition attendee

Could you tell me about some of the more technical aspects of the project? How did you produce the track, and what were its components? How did you make the track play different components of the audio on different speakers?

The data that's used is far too slow to make sound, so we're listening to a representation of 100,000 years in 5 minutes. There are some movements up and down, and if you imagine stretching that out to real time, you would be left with movements that are so slow that there's no sound. Instead, we use that data to control the sound, which means that the soundtrack that we're hearing is something that we design. It's an artistic representation of the magnetic field, with the data controlling the playback parameters of the sound. Each track is combined from different recordings, and data is then used to modulate either the volume of these recordings or the playback speed, so it's data controlling sound.

There are 2 kinds of data sonification processes. One kind is when you directly convert data into sound, which gives you noisy results that literally are the data. The other kind is parameter mapping, which is what we did, where you use data to control different playback parameters. When you have, for instance, those examples from NASA that have an image of deep space, where each star and galaxy plays, say, a piano sound, that's parameter mapping as well.

The sounds that we are hearing are made through a combination of different field recordings. I decided that we needed to have some sounds that were totally organic and would bring the notion of Earth in movement to the spectators. That's why I chose recordings of rocks, wood creaking, and mudslides, for example. I chose all kinds of different recordings which are then combined and processed to make it difficult to pinpoint what each component is when you hear the overall track. It goes together in the mix, and then the result gives a feeling of something organic.

How did the spatial aspect of the presentation work? Was each of the thirty-two speakers representing the magnetic field at a different location on Earth?

Precisely. For the original event at the public square, we had a map of where the speakers were placed on the square, and we imposed a map of the world on that so that each speaker would represent a particular location. That meant that when you were walking on the square, you could say, "Okay, I'm going to go up north now and listen to what the magnetic field is doing up there." When we transposed this to the rental space here in Vienna, we only brought 16 speakers and simply downsized the event.

The reason for the spatial aspect is that the magnetic field is constantly changing, and therefore it's not the same across the globe. For example, at the moment there's a very weak spot in the South Atlantic Ocean, called the South Atlantic Anomaly. Researchers don't really know why Earth's magnetic field is so weak at this point, but it's measurable. We have data that show how satellites in orbit around Earth, whenever they're right on top of this point, are not protected from harmful radiation from the Sun by Earth's magnetic field, so they malfunction frequently. That's why you, when you're representing the magnetic field on the planet, need to represent it locally and in different places.

The Swarm satellites, which you're using data from, were launched in 2013. How did you have access to 100,000 years of data when the satellite system has only been functioning for about a decade?

Of course. We're using data from a model. That means that it's, of course, a guess from qualified scientists what has happened to the magnetic field for the past 100,000 years, but it's based on satellite data and ground observatory data.

> *Even if the track produced isn't completely accurate to the data, as an outreach tool, it's still an inspiring way for sighted and visually impaired persons alike to learn about space science.*
> *- Exhibition attendee*

At the Vienna International Centre, sixteen speakers play slightly different tracks, each a musical representation of Earth's core field. Listeners may walk between the speakers in order to get a sense of how Earth's magnetic field varies spatially. Informative panels explain how the track was produced from data on Earth's core field and the role of sonification in space science.
Credit: Klaus Nielsen

When you finally had all the components of the audio put together, and you heard the finished product for the first time, how did that feel? Was there any particular emotion or impact that it generated?

Of course, it was super cool.

Listening to this multi-channel system is very, very different from listening to something with headphones. You never want to go back to stereo because all of a sudden you can't do without 360 degrees. It doesn't feel as immersive. You need at least 32 speakers. [laughs] That aspect is very inconvenient.

Even with just 16 speakers, the setup here is madness, but it was a very, very rewarding experience. I was working for quite some time on this one project. For instance, I would be sitting with headphones on, trying to hear a mix of 32 tracks, and that's impossible. You do your best and say, “okay, it's probably going to work this way,” and then you release it. It must be similar to a symphony. You're not able to hear the whole thing before you pass it on to an orchestra. [laughs] I just made a comparison to me as a composer. It's because I'm in Vienna, the capital of composers. It’s getting to me now.

> *“As a person with dyslexia, I’ve always struggled with text. Therefore I am extremely excited to hear such an interesting exhibition that converts data into sound. It totally opens up my world by engaging with my sense of hearing, rather than by vision. I am happy to discover sonification and I will recommend this to my friends and others in the disability inclusion network.”*
> *- Exhibition attendee*

Speaking of the project taking a long time, what difficulties did you face while creating this, from the conceptual stage to the design stage to onsite logistics?

We faced the very technical challenge of converting data into messages that my music software could work with. It sounds like the world’s smallest thing, but it took some time to figure out, and then it turned out that there was some simple app that could do it all along.

Apart from that, we’ve had quite tremendous support from the University, who jumped on the idea right away and I also had tremendous support from ESA, who after some consideration decided to fund the project. We were also lucky to get a sponsorship from a audio company in Finland called Genelec which was very kind in lending us 16 speakers that we could bring to Vienna. They even sent an employee down here as well to do some calibration of the speakers.

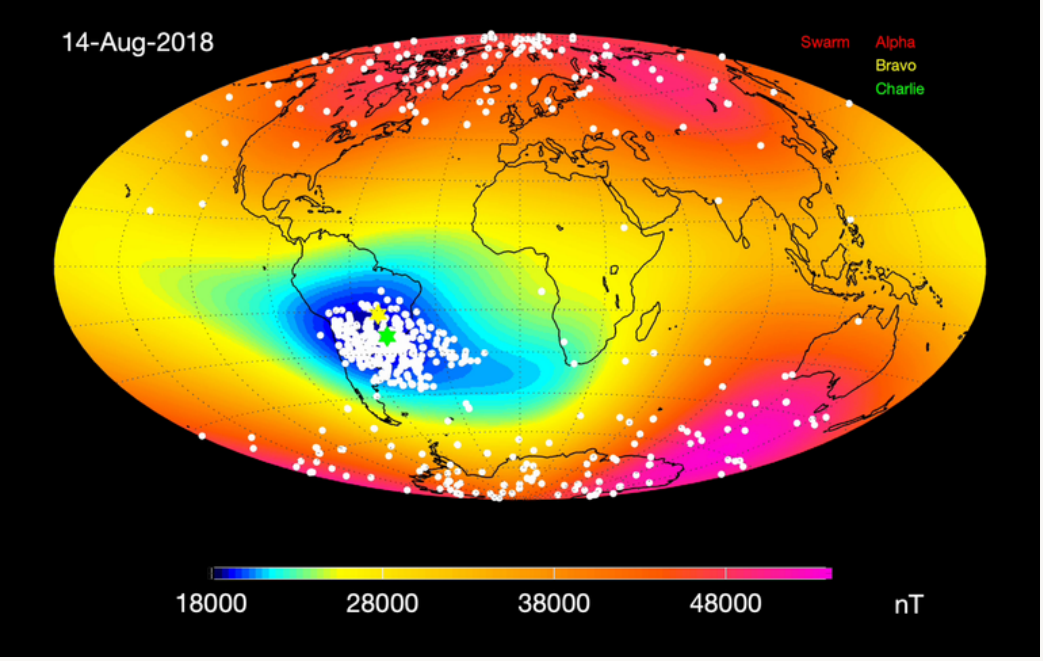
When I first heard the sounds, I thought they were really the sounds of the Earth's magnetic field. But then I thought that couldn't be the case because the magnetic field does not make creaking sound, or any sound for that matter. Then I read the description, and I am impressed by sonification and its potential for inclusion of persons who are visually impaired.
- Exhibition attendee

Do you have any interesting facts about the soundtrack? Did you really sample turtle noises?

When putting together a collection of organic sounds that I could mix, stretch, tweak, and turn weird, I was tapping into all kinds of sources to find audio that sounded like planets breathing, and one of these sources was a recording of a turtle. It might have been the turtle moving across sand with a microphone attached to the turtle, or it might be the turtle eating something.

There's also a classic sound design reference to Star Wars' Chewbacca. They combined different audios to make the sound Chewbacca makes, one of which is a chair being moved across the floor, which makes a weird staccato resonating and rumbling sound.

The track on ESA's SoundCloud is only two channels, one for each ear. We had 32 speakers originally, and I didn't want to put the same sound in each, because that would make it difficult for listeners to realize that there are differences between the speakers. I therefore made about 16 different combinations of sounds that sound similar but are not the same. The two that are on SoundCloud are just two of them. I think there's a recording of wood breaking in one of them, and rocks tumbling in the other.



The Earth's magnetic field varies in strength by location. Pink areas represent a particularly strong magnetic field, whereas blue represents a particularly weak magnetic field (the dark blue area over South America being the South Atlantic anomaly). White dots represent areas where swarm satellites, the same satellites used by this project, have taken measurements.

Credit: Division of Geomagnetism, DTU Space

Will there be another chance for people to experience the full 32-speaker immersive soundtrack?

That would be the next big thing to move on to now that I've been to Vienna with the exhibition. Even this UN building, where the exhibition is now, is not open to the public. You have to sign up for a guided tour to get in.

That's another challenge. Where would you find a venue to set up 32 speakers? I don't think that this concept of speakers dug into the ground is very common. It seems pretty unique, but there are a few other venues which could work. It could be fun to have the opportunity to take the exhibition on a proper tour. I know, for instance, the Royal Conservatory, somewhere in Denmark, has an eight-channel system.

I just need to find all these places, but I don't know how. I've been trying. For instance, there are a number of museums that are focused on geology. Some of them have experience centers for kids, where you have all kinds of non-standard museum items that you can touch and move and interact with. I've been in touch with two of these, and they're very interested in having this project set up as an exhibition if we can provide the funding, which is the tough part. These science experience centers, where you can go and be at a museum but also interact with science, would be an obvious place, I think, to exhibit this project.

What is Sonification?

Sonification is the translation of data into non-verbal sound to facilitate interpretation and communication. This may serve a variety of purposes, including artistic purposes, outreach and education purposes, or scientific research purposes. The space sciences are often perceived to be primarily visual fields, the ramifications of which are twofold. Firstly, this limits the possibilities of data analysis to the capabilities of visual perception. Secondly, blind and visually impaired (BVI) persons are prevented from fully accessing or engaging in space science. In recent decades there has therefore been a move by some in space sciences to widen the sensory parameters of space sciences through sonification.

What are some of the advantages of sonification?

- **Sound perception**: The way humans perceive sound has multiple benefits applicable to space science and data analysis; humans are able to identify sounds in a noisy environment, process background noise, recognize multiple dimensions of sound, recognize temporal patterns in sound, and determine spatial location from sound.

- **Accessibility**: Sound-based science communication and research has potential to enable participation in space science by BVI persons. In fact, several BVI astronomers are currently making use of sonification in their research or outreach activities.

- **Engagement**: Awe-inspiring images are a powerful engagement tool for attracting non-expert audiences to complex subjects and stimulating interest in astronomy; sonification provides an alternative or additional way of inspiring curiosity and wonder.

- **Complex data analysis**: Astronomers often deal with large datasets, tracking multiple important parameters, and often with significant noise obscuring the relevant signal. New methods for data analysis are therefore appealing as a way of finding new insights and tackling the overabundance of data. Adding sound to the astronomer's toolkit can essentially increase the "bandwidth" of data analysis and reveal patterns and phenomena obscured by a visual-only approach.

You've stated that the primary goal of this project was the artistry rather than necessarily making magnetic field data accessible to persons with disabilities, but do you have a sense of what role sonification could play in making outreach and research more accessible?

When I started reading up on sonification, I discovered that it was also being used for people with disabilities. This particular project is far too imprecise for that purpose; you would not be able to get a proper sense of what the data is from the sound we produced. In that sense it doesn't work, so I hadn't put a lot of thought into its usefulness for accessibility purposes.

In general, sonification is a way forward for people who can't access data through visual means, and it would be interesting to try and do more in that sense.

Projects which intend to use sonification as a proper means of inclusion need to process the data such that people can hear precisely what is in the data. There might be future opportunities to make something that is sonically interesting and beautiful while also conveying data functionally and accurately.

How can stakeholders, such as government space agencies and universities, promote the use of sonification for space science? What can institutions do to encourage more work in the field of sonification?

They should be open to art-science projects when they appear and should choose to fund them. There's also the possibility of institutions reaching out to artists. These institutions could choose to initiate these projects and simply call in the artist to help work on them. Most artists are eager to jump on these kinds of things, so that would be a good idea.

> *"[Sonification is] a great way to spread the word about hardcore and heavy science subjects."*

Do you have any plans for future projects in sonification or ideas for future projects that others could pursue?

I'm working on an application for funding for a new project. As of right now, it's just some loosely sketched ideas. One pillar would be continuing this project by getting it into museums and more venues, and another would be trying to make an audio based on the Northern Lights, because sight and sound go very well together. There may be an option to work on this project along with an Aurora Borealis center that's being developed. I'm trying to see if I could do some more of this kind of work, but I don't have a very birds-eye view of sonification. Right now, I'm learning more, and I have a few ideas to see if I can arrange my workday a little bit more around sonification. I hope that they'll work; that could be really fun.

> *"[Sonification is] such a fun and rewarding enterprise. People who are interested should just go for it."*

What advice would you give to people who are interested in learning more about sonification or pursuing a sonification project in the space sciences?

Just go for it. That's not specific advice, I know, but it's such a fun and rewarding enterprise. People who are interested should just go for it. What we've done here has spurred some interest within other ESA missions that are now working on their own sonification projects. It's a great way to spread the word about hardcore and heavy science subjects.

> *"If people want to throw a little less plastic in the ocean, then that would be great. If the project has that effect, then I'm happy."*

Is there anything that hasn't been discussed that you want to add, or any final ideas you would like to leave us with?

Those months where the ESA SoundCloud was boiling over with listens and comments were very fun for me, so I kept an eye on what people were commenting on this piece. Of course, people who listened to the SoundCloud came from all over the place. They weren't there, I think, because they're necessarily interested in science, but a lot of them picked up on the concept that these sounds sound like Earth. Also, a lot of them expressed concern that it sounded like the Earth was not doing well. These people were clearly not reading the description of the sound, nor were they clicking on the ESA links to read the article where they could learn that it was an artistic representation. Some comments were therefore saying, "this is a hoax, because the magnetic field doesn't make sound." That's true, but it's not a hoax, because we describe what we did.

Anyways, these listeners were concerned that Earth is creaking, moaning, and sounding like an engine that is quite clearly broken. It probably doesn't make much of a difference, but people were taking this project and projecting their concern for the environment on it, and the environment needs all the concern it can get.

In that sense that was good, right? I don't think there's any connection between the magnetic field and Earth's environment, and there's certainly no connection between Earth's environment and the sound that we've made, but if people want to throw a little less plastic in the ocean, then that would be great. If the project has that effect, then I'm happy.

"This is my first time hearing sonified data. It is so cool!
- Exhibition attendee"

RESOURCES

- Klaus' website, with more information on this project
- Sonification: From Data to Intelligible Soundfields (Klaus' recommended book on sonification)
- ESA's article on the project
- SoundCloud link
- ESA's Swarm Satellite mission
- More information on the Solbjerg Square exhibition
- A global geomagnetic model of the core field

ABOUT THE INTERVIEWEE

Klaus Nielsen is a Danish musician, producer, and sound artist based in Copenhagen. Since 2020, he has been working in electronic music under the name Maple Pools. The genre is a mix of ambient and electronica, employing samplers and analogue synthesizers to achieve an organic feel.

Nielsen started deejaying in the early 90s and has explored a variety of musical avenues, including several years as a keyboard player in the art rock band Mew. Always on the lookout for new sounds, Nielsen has for the past 10 years been designing and building his own modular synthesizer from scratch, using recycled parts salvaged from discarded electronics.

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