

MAXWELL

Electrotechnische Vereeniging

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Emergent Technologies



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Ampère's law and Faraday's law
Lou van der Sluis, Honorary Member Electrotechnische Vereeniging



LUSTRUM GALA XXIII

GENERATION

DINNER | PARTY | HOTEL

11
February

KASTEEL
MAURICK

TICKETS FOR SALE AT ETV DESK

From the Board

Dear Reader,

When I heard I needed to write a piece for the Maxwell about Mark, my fellow board member, I was very excited since I have known Mark for many years now. Mark and I have been friends since middle school and were very happy to figure out that we were both going to be in the board of the ETV this year. I quickly knew that Mark would be a very good fit for the role of President since I know he has a good leading attitude.

Mark and I have had many good times already and had some pretty crazy adventures, but starting this board year has been one of the craziest yet. From the beginning we didn't know what we were doing, but now, more than 10 weeks later, we are getting used to our roles. Mark especially is fulfilling his role very well. In the beginning he had to get used to the idea of leading the association and being the face of it as well. After getting used to this he manages his role very well; not only is he able to always think about the image of the association he also always makes people feel welcome by making a small conversation in the board room.

Mark is also very well-known with us for his sporting ethics. We don't know how, but Mark always finds motivation to work on his physique. He is actively trying to give us the same motivation, but none of us can bring it up as often as Mark can.

The fact that he is always trying to make us live healthier also says a lot about Mark's personality. He is very caring and doesn't hesitate to run to help people. This is one of his biggest traits and what makes him such a great President as he genuinely cares for the members and wants to know how they are doing. Unfortunately, Mark is very bad with names, and this makes for some uncomfortable moments for him, but very funny for us. It has happened that Mark is talking to someone and during his conversation is messaging me to ask the name of the person.

By Jorrit van Drie



Dear Reader,

When I saw Maxim the first time we came together as a potential board, I was really surprised. Not because I thought of him as incompetent or something, but because I didn't really know him yet. I only knew him as a very energetic and nice guy. Boy, that was an understatement. When you go to a party or have a constitution drink, you can always count on Maxim to be the loudest in the whole club. But also when you come into the boardroom the next day and everyone is really tired, you just know Maxim will be the one to try and lift everyone's spirit. It is probably because he is the youngest of our board that he has that kind of energy.

This year is the first year the ETV has a 6th Board member outside of a lustrum year. The tasks for this 6th member are not yet fully defined so Maxim has to figure out a lot of things on his own. I could not imagine someone fulfilling this job better than he has thus far. From promotion of events to being the main organiser of the Recruitment Days, he can do it all. I look forward to being a board with him for the next three quarters too!

By Maarten Groen



Colophon

Year 24, edition 3, December 2021

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Editorial

Dear reader,

With this edition in your hands, our time as the editorial team for the 24th Maxwell committee has come to an end. During this very chaotic academic year which began –and is unfortunately ending– in a pandemic, we gave our best to inform and entertain you. Our vision as the 24th Maxwell committee was to bring a range of topics, as versatile as possible, to your desks. To get our inspiration for this year's Maxwell editions, we met many interesting people and heard their compelling stories. I express my utmost gratitude to all of them for giving us their time and interest. Without them we would not have the content to write our articles, but what could we do with just content without the people to polish and publish it? Lots of gratitude, therefore, goes to my colleagues Neil Dani, Natasha Birari, Merel Verhoef, Aniruddh Kulkarni and Nitish Kulkarni. It was an enriching experience to fulfil my role in the Maxwell committee.

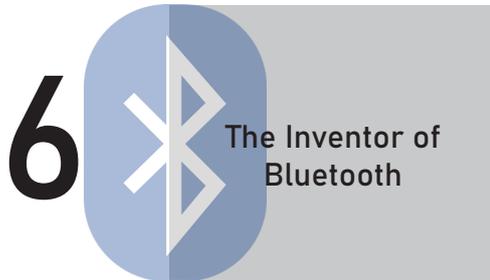
As a very wise man once said: "Science is the only true guide in life". With this determination and vision, our purpose of existence as engineers should be to enlighten the path of humankind with the torch of positive sciences in our hands and minds. Striving for a society where each of its members has access to the broadest means and sources of welfare should be our motto.

But enough with the sentiments, enjoy this last edition. Bye!

Yunus Emre Döngel



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The Inventor of Bluetooth

An interview with Jaap Haartsen

With the past lustrum year it was again time to commission new honorary members to our association. This time the nominees were Jaap Haartsen and Arno Smets. We had the chance to have an interview with Jaap Haartsen who is an alumnus of our faculty (1986) and finished his phd in 1990. He is known as the inventor of Bluetooth.

It is hard to find a lot of information about you. Just some resumes. Could you please tell us something about yourself?

Yes I do appreciate privacy. As a kid I was always interested in engineering. I built things with Lego and Fischertechnik. Then I became interested in electronics. I got that from my dad, who was a mechanical engineer at Siemens. I really liked electrical engineering with its currents, motors, that kind of stuff. So after high school I started studying in Delft and I really enjoyed it. I started in '81, graduated on 20 November '86, and finished my PhD four years later also on 20 November 1990. I did all of that in instrumentation: surface-acoustic waves; the interaction between acoustic waves and silicon surfaces. The applications of that were in the field of filters for communication systems. That's how telecommunications gained my interest, although I was more concerned with components and semiconductor physics, and not with entire systems. When I finished my PhD I got into contact with Ericsson in Sweden, the telecommunications giant. It seemed interesting to me, so when they offered me a job in the United States, I went, together with my wife and newborn daughter.



ter. The group there was just starting and we were amidst the transition from analogue to digital mobile telephony. After 2.5 years at Ericsson, where I had learnt all about systems, communications, propagation etc., I had to either apply for a green card to stay in the States, or go and do something else. I had enjoyed my time there, but not for much longer, so we moved to Malmö, the southern-most tip of Sweden. Ericsson's headquarters are in Stockholm, but their mobile communications division is located in Lund, close to Malmö. It was my job to look into wireless communication between devices in homes. Not only between phones with speech, but also data communication with for example a laptop or a tablet.

Were you a radio-amateur as a kid? That used to be hip.

No, I'm not a radio guy at all. During

my studies I also didn't care a lot about radio. I always liked working with electronics, semiconductor physics, but the radio field never really crossed my path until I went to work for Ericsson. That's where I learnt everything about it. When I was young I had some breadboards, soldered some components, but it drifted away from me during my time at the university. I'm not very much someone who solders. It may sound odd, but I'm someone who contrives things, and let other people build it.

So less hands-on, but more thinking?

Yes, of course I work with people who are very good at that, so we're a good team. Even at home I'm not a radio amateur who puts together all kinds of capacitors, transistors, and tubes.

But you could be...

Yes I could be, but I'm not. I'm more the one who runs simulations on their computer about propagation and then lets their colleagues check it in practice with their network analyzers.

What did you do about the Bluetooth technology? Are you the inventor or developer?

Am I an inventor? I have many patents in my name, but Bluetooth consists of many different parts. Bluetooth itself is not an invention, but the parts are, so actually I'm more of an architect. I started working on it in '94. I was asked to develop something, and by that time, nothing else existed. I was the only one working on it. As an engineer you look for what already exists; what can be reused? But the existing things were very asymmetric. They used base stations or a hotspot connected to a network, which then would communicate with portable devices. But I had to develop something for communication between portable devices with batteries, devices on the same hierarchy level. That's a completely different system, called ad hoc network, or peer-connectivity. Such a thing did not exist back then, and I built the fundamentals for that and I got a lot of patents for Ericsson because of that. So in that sense I am regarded as the inventor of Bluetooth, because I was the first to develop the architecture for that and I am proud of the fact that it still exists. Things like frequency hopping, and how they hop are still in there.

Did you develop that in a research group or did you do it on your own?

I worked for a manager who said: "The way we develop things here is as follows: one person starts with it, can focus on it, sees all kinds of connections. And when you've got

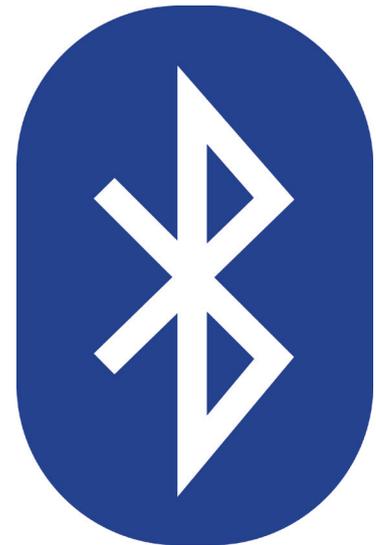
that you can make a specification or description, and we'll discuss it with a group." So for one year I was working on my own. After that people joined the project. I'm not the one to put it together, so we had people for the implementation. They would ask if I could make some slight changes, so that the implementation would be easier. Then software people would join, and so on. I really went bottom-up, starting with the antenna, all the way to the top. At some point I also don't know how the software should be implemented, due to limited knowledge. But then you're a couple of years down the road. The fundamentals, the architecture part, I was responsible for that.

Did you keep the overview during the entire development or did you let that go at some point?

No, at some point I let it go. It became too big, and I'm a scientist, so I'm always interested in the next thing. After a couple of years it just needs to be executed, so I'll start looking into something else; new features, new releases. There was also a period when I didn't work on Bluetooth, but for example 4G. I always make sure that I work on new things.

Why is it called Bluetooth?

When I started it was called MC-link, Multi-Communicator link. The idea was that there was some kind of tablet, the multi-communicator, which would communicate via your mobile phone with the cloud or a network. The MC-link was only a minor part of that system, the link between phone and tablet. After a while the MC died, but the MC-link remained and Ericsson realized that they could develop such a link, but they did not manufacture devices like tablets or accessories that would actually communicate with mobile phones,



so they had to find a way to involve other companies too. They wanted to set up standardization for ad hoc networks and hence change the name of it. One of the affiliated companies at that time was Intel, which put some PR folks on it. One of them talked to a Swedish colleague of mine, who told the Intel guy a story about Sweden and Scandinavia from around the year 950. It was about a Viking king Blåtand, who lived in Denmark and brought peace amongst people. So they came up with a story that like king Bluetooth this communication system can bring people together. Also, the name was free to use. When you would google Bluetooth, you would only find the story about the king. There was no company called like that and most people around the world can pronounce it correctly more or less... well except for Dutch people maybe haha. So that is how Bluetooth got its name. Also, when working for a company, every project has a name. For phones we used girls' names like Sandra or José. That way, whilst drinking in a bar and talking to colleagues, no outsiders would know what you would be talking about. We did not intend to use Bluetooth as the commercial name. The marketing division back

in 1999 thought of PAN, Personal Area Networking, but that name was already used for something else, so the name remained Bluetooth and that's what we went with.

And what about the logo?

That's also a funny story. We had a logo, some kind of triangle with three white stripes resembling a radio wave, kind of like the wi-fi symbol you now see on your laptop. We used that logo during the system launch in 1999. All PR and magazines used that logo, but then some half year later the Dutch association of publishers (VNU) came after us, because their logo looked exactly like ours. They said "This is our logo, and we have all the rights.". So we had to come up with another logo. That task was delegated to a commercial company, which combined the rune characters for "H" and "B", the initials of the Viking king Harald Blåtand, which is the logo we now know.

Did you ever expect Bluetooth to become such a ground-breaking invention?

No. Well you never know. I just have the feeling that I was in the right place at the right time with the right people. To get something like this off the ground, that does not just take engineering, but also marketing and millions of euros of investments. It cannot be done by one individual person, and I am interested in science. At that time I was not concerned with setting a world standard. Looking back at it, that was just a nice side-effect. Of course I am very proud of it, but the development went gradually. First you start the research project, work on it a couple of hours per week, then something is built. It takes years before all of the marketing people get involved. When it got really big around 2004 and 2006, when all of a sudden millions



Bluetooth logo between 1998 and 1999

of devices were sold, for me that was 10 years since the start. I was already working on the next thing. But then all of a sudden you wake up and billions of Bluetooth devices have been sold. That is something that I caused, my thoughts are in there, and at some point you walk through the mall and see it everywhere, everyone's talking about it... that is really exciting. For other people it's there all of a sudden, but it took years and years of preparation.

I actually already know the answer to this question, but I'm still going to ask it. I read that you didn't get rich off of it.

Haha you're Flemish. Usually it's Dutch people asking me that question.

Indeed, but what I actually want to say is that society expects people who invent something this ground-breaking to get rich off of it. Like Mark Zuckerberg or the CEO of Instagram; they invented something and turned super-rich at once.

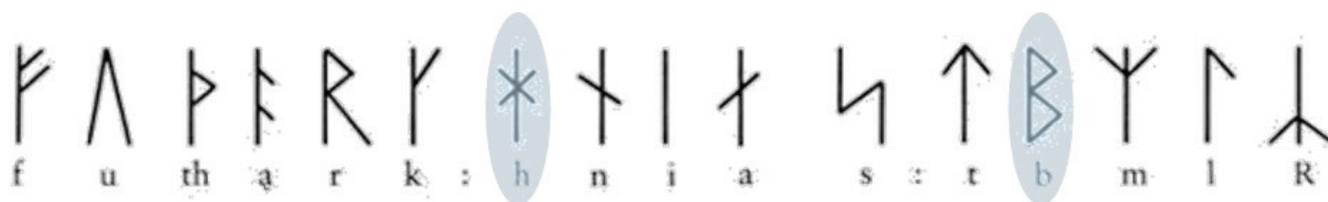
The thing is; how many things can you do on your own account? When speaking of Facebook, you can create that by yourself, set it up, and roll it out. Bluetooth however, involves many more factors; not only Ericsson, but all of the



logo of VNU (Verenigde Nederlandse Uitgeversbedrijven)

other companies. In order to develop communication architecture, you need to develop chipsets, for which you need huge investments. Millions of dollars were put into that before something came out of it. Can you achieve that as a single person? Get the entire industry to back you? Ericsson went to Nokia, IBM. If I would have gone to Intel as myself, they would have told me "Nice idea, bye". I would not have had the power of persuasion Ericsson had. I was employed by Ericsson, and everything I did was property of Ericsson. My name is on all of the patents, but Ericsson is the owner. And I don't really care about it. I enjoy developing new things. I'm a scientist and I don't need to be a millionaire. Would be nice of course, but then I would still be working, because I like to spend my time in a useful way. It didn't make me poor either. If I would have gotten a cent for every device sold, I would be a multimillionaire. But I built my reputation and now I can decide what I want to do and what I don't. I can pick the cherries, and I'm satisfied with that.

How do you feel about being inducted in the National Inventors Hall of Fame? You're in there alongside Edison and others. How does that feel?



Initials Harold Blåtand in Rhune Alphabet, making off Bluetooth Logo

I see it as a kind of Nobel prize for inventors. Initially I didn't quite grasp the importance of it really, so I texted several people asking whether or not this is serious. I often get requests, like with the ETV to become an honorary member. But this turned out to be serious and it's really nice. I was inducted in 2015, and it's organized by the US Patent and Trademark Office. It is quite an honor, since your name is up there next to Edison and other important inventors. What's funny, is that I'm invited to join the ceremony for the new inductees every year, and then you get to meet your fellow inventors and think "hm well this all was invented too". For example the yellow post-its. Then you talk to the guy who struggled with that. And people who created artificial skin for burns, or eye lasering technology. You meet that kind of people and that's very funny, as inventors

among themselves. That might be the best part of it, even better than the name tag.

What do you do in your spare time?

I could stop working, retire. But I don't think I ever will. The things I do not really feel like work, but like a hobby. 70% Of my time I'm busy with work, 30% I spend on recently discovered new hobbies. I like gardening now, I have a large garden with a vegetable garden. In the past I wasn't interested in that at all. I didn't even take biology classes. I was a techie. But now I enjoy it, so that's what I do. I also got into music, started playing saxophone a couple of years ago. And of course I also spend a lot of time with my family, the children.

Were you an active member of the ETV?

I have to admit that after graduating high school I got a girlfriend

and I didn't feel the need to spend a lot of time in Delft. I studied in Delft and lived in Monster, where I had my girlfriend. So I didn't join student or study associations, but I do feel sympathetic about the ETV, because they provided books and lecture transcriptions. So I used that a lot and profited a lot from that.

We want to thank Dr. Ir. Haartsen for his time and interest in our interview and wish him all the best in his further career. It was an honour for us to meet and talk with the person who invented the technology that greatly changed our lifestyle and wrote his name in history.

The Honeywell-96 instrumentation recorder: What was magnetic tape recording again?

Otto Rompelman

Introduction

Taking measurements without recording the results is rather pointless. Therefore, scientists and/or engineers have always tried to find new and suitable ways of recording their results. The methods used range from simply taking notes with pencil and paper to applying highly sophisticated data-acquisition systems. When it comes down to rapidly varying quantities, we need instruments for their registration. Before digital techniques took off, analogue registration was quite common, using magnetic tape recorders. The best-known applications are in sound recording with reel-to-reel and compact cassette recorders, and in video-recording using systems such as VHS and VCR. However, in many other fields there is the need for

recording sensitive measurement data, such as in biomedicine using the well-known ECG (electrocardiogram) or the EEG (electroencephalograms). Other fields with a similar need are geophysics (seismography), aerospace (flight recorders, wind tunnel experiments) and hydrology (model studies).

For all these purposes, a special class of magnetic tape recorders has been developed usually, referred to as instrumentation recorders. In this contribution some technical aspects of instrumentation recorders will be explained, with special emphasis on the Honeywell-96: an interesting example present in the historic collection of our Electrical Engineering department.



The basics of magnetic recording. Though a thorough discussion of magnetic recording is beyond the scope of this article, the main aspects are illustrated in figure 1.

The magnetic tape consists of a plastic base (usually acetate or mylar) and a coating of ferrous oxide particles. Commonly employed thicknesses are 0.5 mil, 1.0 mil and 1.5 mil (approximately 13 μm, 25 μm and 38 μm). The tape is transported from reel 1 to reel 2. The tape passes over a small idler before passing over the recording and the reproducing heads (write and read head). The tape then passes in be-

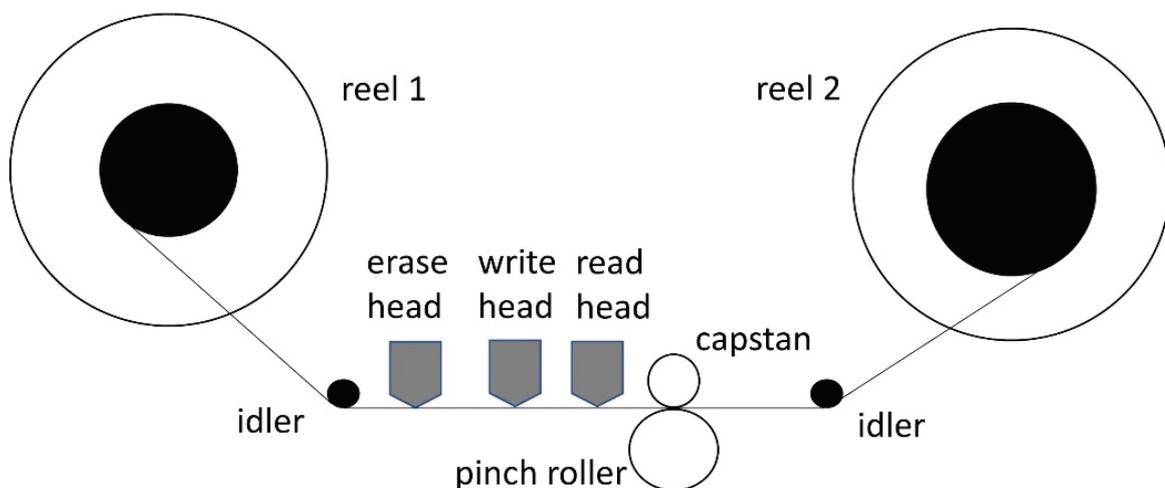


Fig 1: The basic tape recorder

tween a motor driven capstan and a rubber pinch roller, hence being transported at a constant speed. After leaving the drive mechanism the tape passes another idler and is then fed to the second reel. Both reels are powered by separate motors. As will be discussed later in more detail, it is crucial to keep both the tape speed and the tape tension constant.

Magnetic registration

The tape is coated with an acicular (needle shaped) form of ferric oxide (Fe_2O_3). The particles are about 0.2 to 0.8 μm long with a diameter of about 1/2 to 1/6 of its length (For audio purposes, chromium dioxide (CrO_2) was also used.) First the tape is demagnetised by an erasure head to prevent residual signal magnetisation. Magnetisation of the particles occurs when the tape passes a recording head basically being a ring-shaped ferromagnetic core or mu-metal core and a narrow gap that is a few μm wide (figure 2).

The signal to be recorded is fed to a coil, hence creating a fluctuating magnetic field. Thanks to the narrow air gap, this field penetrates

the tape, thus magnetising the particles on the tape. The net result is a remaining magnetisation which is dependant on the originally applied field strength.

Unfortunately, this relation is highly non-linear. It can be proven, however, that, if a high frequency bias current is superimposed on the signal current to be recorded, the net result is a linear relation between the signal current and the remaining magnetisation of the magnetic particles on the tape.

Recovering the signal is accomplished by a replay head similar to the recording head. The variations in magnetisation of the tape passing the gap in the read head give rise to fluctuations of the flux Φ induced in the head. Consequently, a voltage $u = d\Phi/dt$ is induced in the coil of the head. It follows, that the regained signal is the derivative of the recorded signal. Obviously, this can be corrected with an integrating circuit. However, it becomes immediately clear, that the recording of DC or very slowly fluctuating signals is impossible. At the other side of the spectrum, we find that the maximum pos-

sible frequency to be recorded is dependant on both the tape speed and the gap width such that: $f_{\text{max}} = v/d$ with v being the speed of the tape passing the head and d the gap width. In practice the value of $f_{-3\text{dB}}$ is much lower than f_{max} .

Deviations from perfection

Ideally, the tape passes the head without any mechanical distortion and at a constant speed and with perfect mechanical contact between tape and head. However, the tape drive system (capstan and pinch roller) and the reel motors exert a longitudinal force on the tape causing mechanical tension. Fluctuations in the tension cause length variations and hence frequency fluctuations. In audio applications, the audible effect is usually referred to as 'wow' (low frequency fluctuations of less than about 4 --10 Hz, usually due to imperfections in the tape drive system) or 'flutter' (higher frequency fluctuations usually due to the combined longitudinal force on the tape and the stiction at the head. The tape may even vibrate, as if it were a bowed string of a violin! All these effects can be minimized by stabilizing the tape tension.

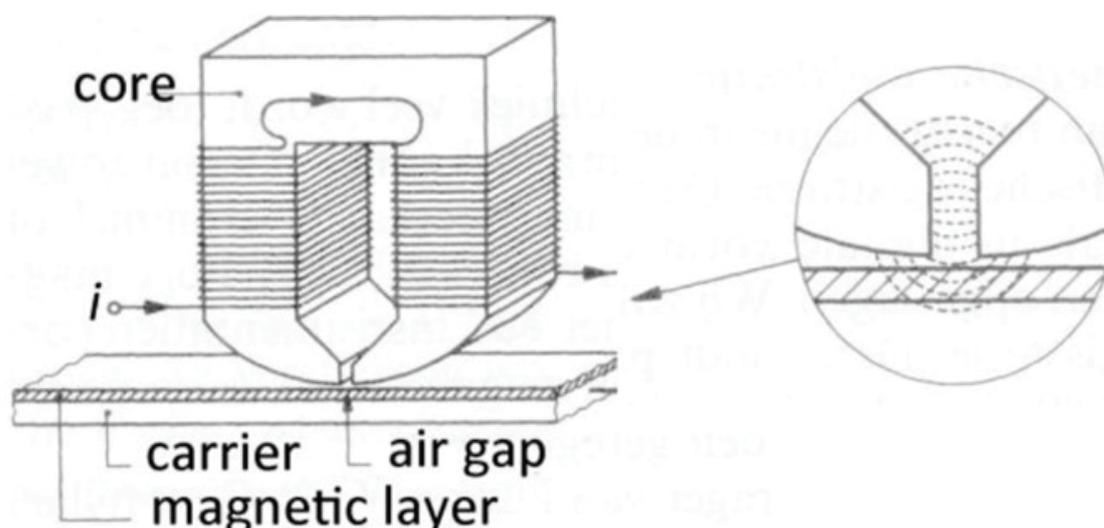


Fig 2: The recording head; detail: magnetic field penetrating the magnetic layer of the tape [1].

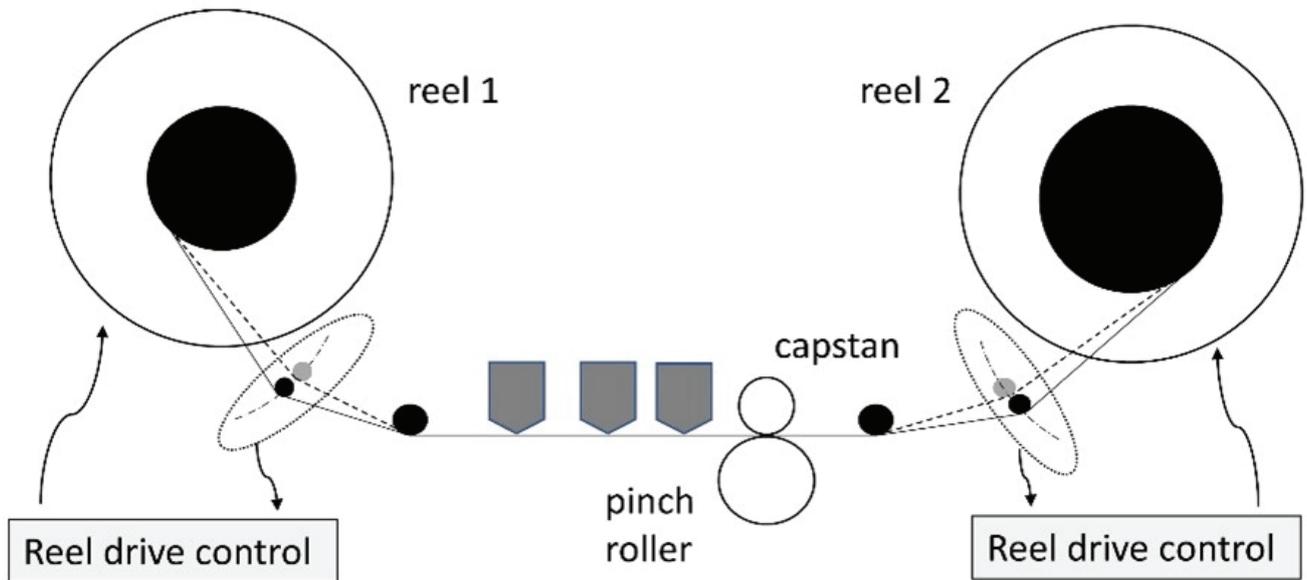


Figure 3: Tape tension control

Therefore, it is of utmost importance to keep the tape tension constant. Two strategies are applied to overcome these problems: The first one is obvious: try to prevent the problems from occurring. If this is not fully achieved, the next strategy is to reduce the effects by some way of feed-back control. The first approach leads to minimizing the distance between the drive mechanism and the heads. The second strategy consists of controlling the tape tension. Taking into account that rapid fluctuations have to be reduced, we need a fast-responding control system, which imposes special requirements on both the sensor and the actuator.

Traditionally, the tension sensor consists of an idler mounted on a movable arm connected to a potentiometer (sensor). This is called the open loop drive system. The output of the potentiometer is used to adjust the power of the reel motor (actuator). Since the sensor is a mechanic system the response speed is rather limited. Figure 3 shows the traditional system for tension control is shown.

A rather different tape transport

and tension control system will be described later when discussing the Honeywell-96 machine.

FM-recording

As mentioned previously, it is not possible to record D.C. or very low frequencies. However, in many applications we want to record signals with frequencies ranging down to 0 Hz. Think of an Electrocardiogram, which is zero valued, apart from periodical electrical heart activity. The solution is to apply frequency-modulation (FM). A carrier (sinusoidal waveform) of e.g., 10.000 Hz is frequency modulated with the actual signal to be recorded. When replaying the tape, the output signal is fed into an FM-demodulator such as a Phase Locked Loop.

We should keep in mind, however, that the bandwidth of an FM channel is much wider than the bandwidth of the modulating signal, which hence limits the allowable bandwidth of the signal to be recorded. Another interesting point is the effect of imperfections in the tape transport system that give rise to frequency fluctuations ('wow' and 'flutter'). In FM recordings, the fluctuations man-

ifest themselves as fluctuations in amplitude, hence: noise or, in the case of periodical fluctuations: undesired tones! Again, this imposes high requirements on the entire tape drive system as well as the tension control. In general: FM recording is less sensitive to amplitude fluctuations (irregular tape-head contact) and non-linearities, but the achievable band width is much less (by a factor of about 0.1).

Some aspects of instrumentation recorders.

In practice, the tape has a number of parallel tracks so that we can record more than one signal simultaneously; and the wider the tape, the higher the number of parallel tracks that can be recorded. Commonly used systems employ ¼ inch tapes for 4 channels (e.g. RACAL Store 4), ½ inch tapes for 7 channels (e.g. RACAL Store 7, Philips Ana-log 7) and 1 inch tapes for 14 or more channels (e.g., AMPEX PR2200, Honeywell-96). For FM recordings the Inter-Range Instrumentation Group (I.R.I.G.) has defined a number of standards concerning FM-recording: a common standard is shown in Figure 4.

The Honeywell 96

In the mid-seventies of the last century, at that time working at the Bio-medical Engineering Lab of the Department of Electrical Engineering at the TU Delft, I was able to purchase a refurb-

ishment there (Figure 5). Its dimensions are 55 cm wide, 73 cm deep and 185 cm high. The apparatus is a 1 inch tape machine with 14-channels suited for either direct or FM recording. It can run at 9 different tape

Firstly, the tape-drive system is constructed such that a smooth transport of the tape is guaranteed for both forward and backward playing. Secondly, the head contact and tape drive have to be placed close together in order to

Tape Speed Inch/sec	Carrier frequency f_0 kHz	Modulation frequency f_m kHz
1 ⁷ / ₈	6.750	dc – 1.250
3 ³ / ₄	13.500	dc – 2.500
7 ¹ / ₂	27.000	dc – 5.000
15	54.000	dc – 10.000
30	108.000	dc – 20.000
60	216.000	dc – 40.000
120	432.000	dc – 80.000

Fig 4: The I.R.I.G. standards for Wide Band Group I FM recording; Modulation index $\Delta f/f_0 = 0.8$ [4]



Fig 5: The Honeywell-96 Instrumentation tape recorder (front door opened, circuit compartment not shown)

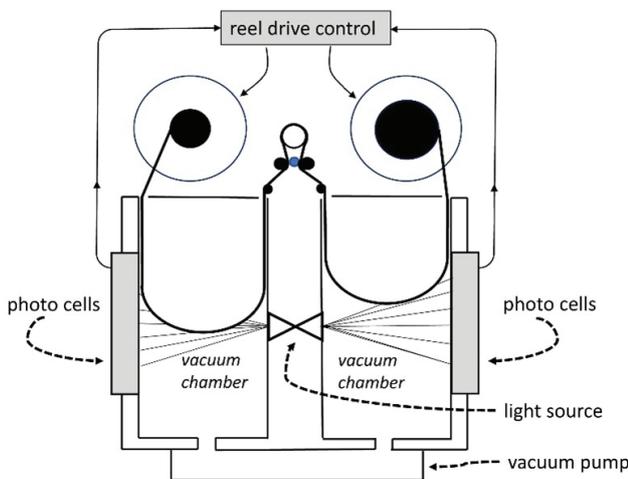


Fig 6: The 'vacuum' tape tension control system (viz. [2])

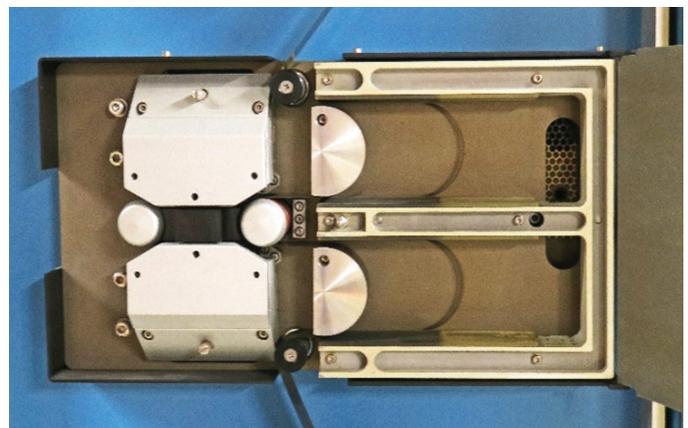


Fig 7: The tape drive, head stack and vacuum tape tension control unit

bished Honeywell-96 analogue instrumentation tape recorder. This purchase allowed us to replay, analyse and process ECG's as recorded in academic hospitals. When I joined the 'Studieverzameling' a few years ago, to my surprise, I found this huge in-

struments ranging from 15/16 inch/sec to an amazing speed of 240 inch/sec (6 m/sec!). This latter figure means an amazing speed of 5 m/sec! It may be clear that the design of a tape tension control system for such a device must have been a real challenge.

avoid any fluctuations in tape-head contact. This leads to the so called closed-loop tape drive system. Thirdly, such high tape speeds require a fast-responding control system which means that the sensors (plural, since the tape has to run both forward and

backward) should ideally contain no mechanical parts. The actuators (i.e. the reel motors) should allow for extremely fast responses, or in other words: extremely high angular acceleration. This can only be accomplished by very powerful reel motors. The solution to the sensor problem is a 'vacuum' tape-tension control system, as depicted in figure 6.

The tape, before and after having passed the transport system, is 'sucked' into low pressure chambers. The low pressure is created by an air pump. Two light sources and two arrays of photo-voltaic elements determine the positions of the tape loops in the low-pressure chambers. The output of the photocells is fed into the motor control systems such, that an equilibrium position of the tape is

achieved. In this way the inertia of the measuring system is determined by a small and hence noticeably light segment of tape, which leads to a very fast response time.

The Honeywell-96 tape transport unit is shown in Figure 7, along with the sensor part of the tension control in opened position. The tape is at the reference position. During operation, this section is firmly closed as to allow for the vacuum-system to operate properly. The need for fast responsiveness of the reel drives has led to the use of heavy motors, which can be observed in the photograph of the machine's interior (Figure 8). Part of the vacuum system is also shown (the yellow hose).

Finally, Figure 9 shows the plug-in rack containing the recording and

replay modules for the individual channels. As can be observed, many of them have been disappeared over the years....

Final remark

After the introduction of digital techniques, analogue recorders were still used together with pulse-width or pulse code modulation. However, the development of fast digital disk systems and solid-state systems finally made tape recorders obsolete.

Acknowledgements:

The critical comments of Kees Pronk and Piet Trimp are gratefully acknowledged. The useful remarks of the reviewer led to significant improvements of the text.

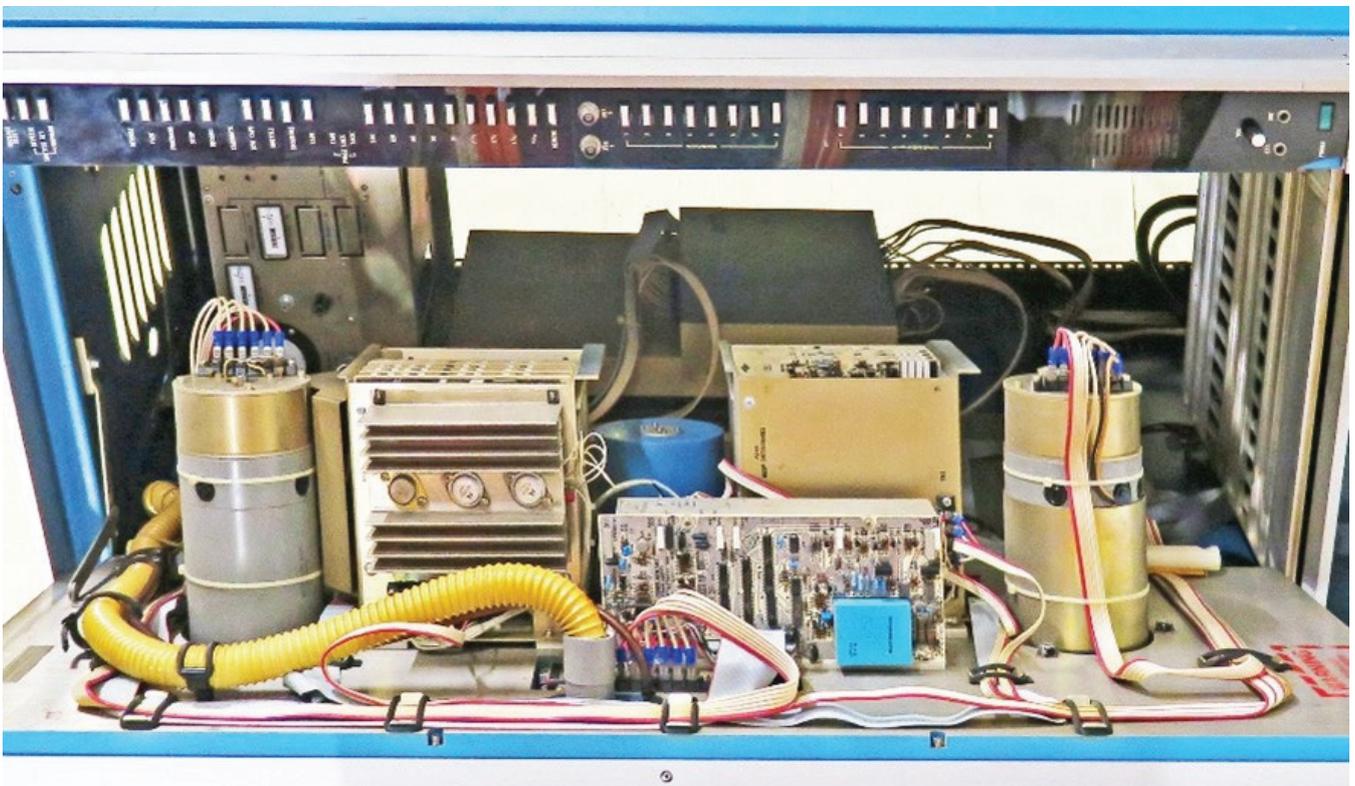


Figure 8: Inside of the machine: note the large reel motors and the yellow hose of the vacuum system

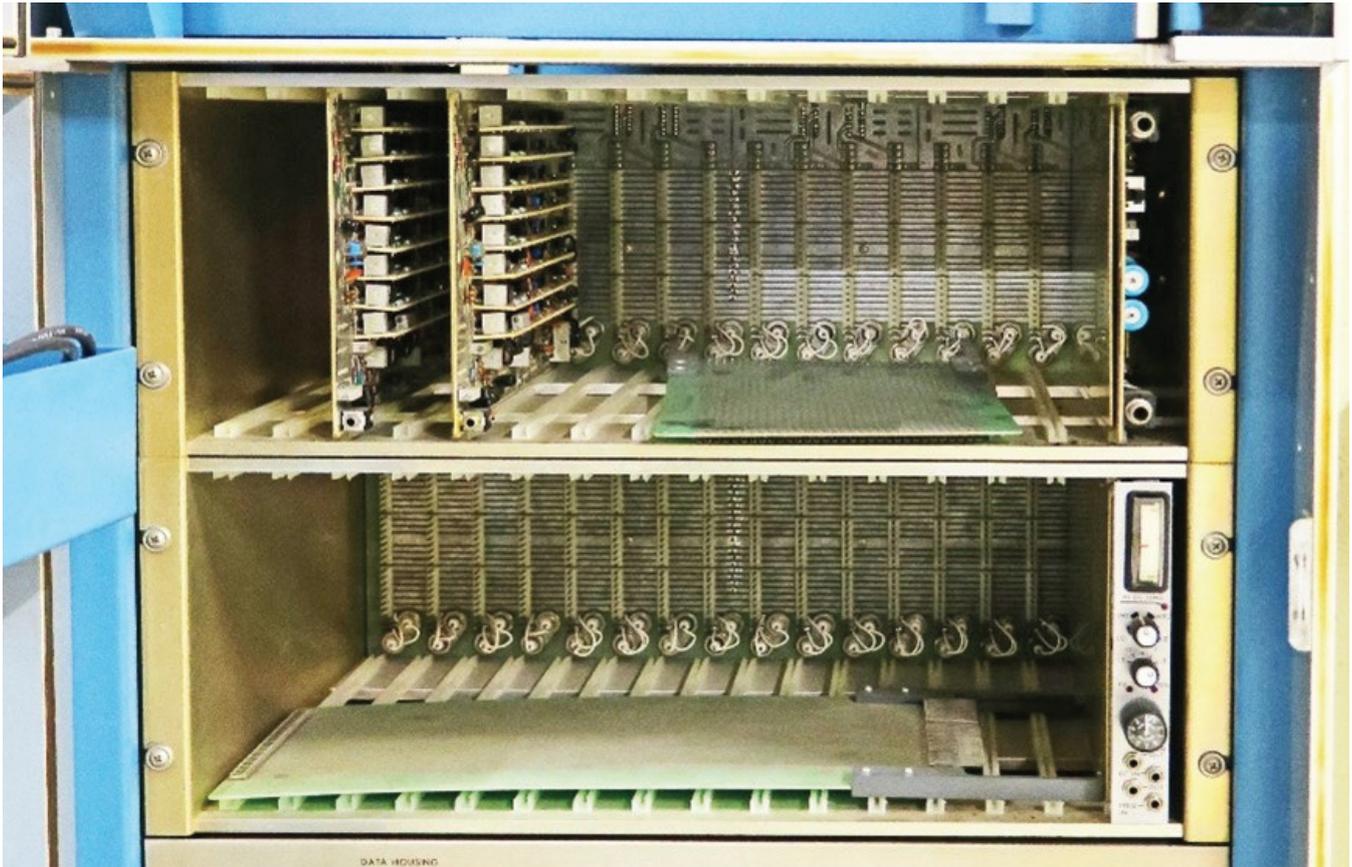


Figure 9: The record and replay units rack.

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All photographs and figures, except Figure 2, are produced by the author.

Want to see one of the few operational Honeywell-96 machines in some serious action? Scan the QR code!



The Flying-V Project

Interview with Yavuz Cinek, by Nitish Kulkarni

For this interview we have spoken with Yavuz Cinek. He is a second-year Master Student in the field of Sustainable Energy Technology. He obtained his Bachelor degree in Marine Technology, also in Delft, having done a switch from the Faculty of 3mE. Yavuz is now focused on his Thesis Graduation Project with TNO and the Intelligent Electrical Power Grids group, on the topic of hydrogen modelling in power systems, optimized for operation and investments. Last year he has successfully participated in the Joint Interdisciplinary Project (JIP), having participated in a project for Airbus and Dutch consultancy firm ADSL (founded by ex-Fokker employees), to assess the possibility of a hydrogen powered Flying-V.

What is the Flying-V concept and how did it evolve as an idea?

The Flying-V is a novel and disruptive type of aircraft architecture enabling a serious fuel reduction. The Flying-V came alive as an idea of Justus Benad from the University of Berlin when he was working on his thesis for Airbus Hamburg. Later on, TU Delft picked up this idea and under the leadership of dr. Roelof Vos from the Aerospace Faculty of TU Delft the concept aircraft is being further developed. Partners on these developments are amongst others Airbus and KLM. Last summer, a scale model of the aircraft was tested, checking for its behaviour during flight operation. The test proved to be successful and simultaneously the project is further developed by both academics and students

at TU Delft. One of these developments, was the Joint Interdisciplinary Project at which we came into the picture. The Joint Interdisciplinary Project is a second-year Master project for students from all faculties at TU Delft, designed to do a project for industry within an interdisciplinary team. We, as a group of 5, were assigned by Airbus and ADSE to take part in this 10-weeks journey, where we investigated the possible implementation of hydrogen as a fuel for the aircraft.

What are the key features of the Flying-V Project?

When you need to explain the key feature of the Flying-V, of course, there is one major thing that is 'right there': the aircraft design. Normally an aircraft has a single cylindrical fuselage, the main part of the aircraft where the passengers are seated and the cargo is loaded. However, in the Flying-V concept, two fuselages are combined to generate lift. Current calculations situate the efficiency of the Flying-V 20% above the Airbus A350, which is taken as a reference aircraft.

The Flying-V concept is often confused with a Blended-Wing-Body concept, another futuristic aircraft concept currently being developed by Boeing. However, the big difference is that the centre of the aircraft in the Flying-V is not being used, hence the name. This reduces the drag induced on the aircraft. Additionally, this configuration solves another major challenge that a Blended-Wing-Body concept does



have. Namely the fact that the evacuation regulations being stipulated for aircraft are being tackled by the design of the Flying-V, where the passengers are allocated in the wings. Lastly, I think it is good to mention that the wingspan for the Flying-V is as much as the Airbus A350, with a span width of 65m. This means, there is no change required in terms of airport infrastructure to fly with these types of aircraft in the future.

How is the Flying-V design more sustainable than a normal aircraft design?

The Flying-V is not necessarily 'the sustainable solution'. Of course, there is a reduction in fuel consumption due to its higher efficiency, but that does not mean it is solving the issues in terms of sustainability. In the end, if you are using kerosene as a fuel for any type of aircraft, you are still making use of fossil fuels which are both finite and having a tremendous impact in terms of emissions. As research conducted in 2018 shows, the aviation industry annually

contributes to 2.4% of human-induced CO₂-emissions. The forecast is that these emissions will continue to grow to 3-5% of the global total by 2050. These predictions are already including a 2% annual efficiency improvement on aircraft, which is counter-weighted by the growth of the industry.

If only compared within the transportation sector itself, on a grams / ton-mile comparison, the aviation industry is 6 times worse compared to the nearest biggest polluters of CO₂ (being trucks). These are all facts and figures one might think of as a doom scenario, so if we look at it from a positive perspective, the Flying-V enables the aviation industry to leap forward in 20% fuel efficiency. But it is not limited to this solution only, as first predictions estimate the configuration might also be very suitable for other types of aircraft fuels.

What is the fuel being used for the Flying-V and what is the other type of fuel you refer to?

The Flying-V is now designed as a kerosene fuelled aircraft. However, it seems particularly interesting to design this aircraft with hydrogen as a fuel. To understand why this might be a viable option, we have to zoom out a little bit. First of all, we have touched upon some of the emissions in your previous question. However, there are more goals and targets. For instance, Airbus has set goals for the year 2050 in terms of emissions from their aircraft as: '50% less CO₂ and 90% less NO_x'. If one would assume a one-on-one relation between fuel reduction and emissions, one could simply state that the Flying-V takes the

CO₂ and NO_x emissions down by 20%, meaning it is not sufficient.

Then hydrogen as fuel comes into play. The Flying-V itself will not be in our skies soon, as it can take between 15-30 years for an aircraft to be produced from the scratching table. This means the expected shift towards the hydrogen economy can go hand-in-hand with the developments for the aircraft.

Looking at it from an aircraft design perspective, the Flying-V seems particularly interesting for hydrogen implementation as well. Hydrogen is a high energy-dense fuel, but the volumetric density is very low (about 4 times lower than kerosene). This implies, there is a big storage requirement on the aircraft. Often it is seen that aircraft are retrofitted with storage above the cylindrical fuselage or some of the fuel is placed in the aft of the aircraft. Normally, the fuel is stored in the wings of an aircraft, but for the Flying-V the wings are also the fuselages. As the tanks are directly placed within this oval structure (see it as a pressure vessel), no extra structural reinforcement is required as would be the case in conventional configurations. The Flying-V geometry itself yields a 20% efficiency increase, effectively leading to a lower fuel demand which is also beneficial when storing hydrogen, taken into account the previous

mentioned volumetric energy density. Every cubic metre saved is a step closer to the realisation of this new aircraft configuration.

Furthermore, the aircraft architecture gives room for flexibility, as the design is not set in stone yet, meaning the incorporation of hydrogen can be considered from the start. Lastly, the Flying-V has spare room in the trailing edge of the wing, making it possible to store pressure vessels within these edges, as well as the fuel supply system.

What impact does it have on the performance of the aircraft? Also, does it affect the environment?

The implications of flying on a different fuel can be tremendous, depending on the way the fuel is utilized onboard. To be clear, our research only focused on the possible implementation of hydrogen in the aircraft. So the hydrogen production, storage and infrastructure outside the aircraft was not within the scope of the research. But if you make use of hydrogen as a fuel, you need to think about how you store it and how you use the fuel for propulsion onboard the aircraft.

Weight is an important parameter for an aircraft, as the heavier your aircraft is, the more fuel it will require. This is like a snowball effect, where one triggers the other and so on. Therefore you want to make use of your



space as efficient as possible, from the simple analogy, the fewer materials, the lesser your weight. But as mentioned, hydrogen is less voluminous, because it is in a gaseous state at room temperatures and standard atmospheric pressure. Meaning you have to either compress it (to above 350bar) or cool it down to create a cryogenic form of hydrogen (to below -253 °C) and store it more densely. There are also other means of storage for hydrogen, such as within metal hydrides, but then the storage compartment becomes too heavy. As you can see, this is just one parameter that can influence the performance of the aircraft. But there are many others, similar to these, such as on the way the propulsion system is designed, think of fuel cells, direct hydrogen combustion or by creating synthetic aviation fuel.

The effects on the environment are rather positive. The emissions of CO₂ are totally taken out of the equation, as there are no hydrocarbons involved. Similarly, the NO_x emissions are also reduced tremendously or taken out of the equation depending on the propulsion system. Also, other emissions, such as soot and SO₂ are totally taken out of the equation.

However, there is a downfall of it all, as of course with the combustion of hydrogen, water vapour is being emitted. At a higher altitude contrails and Contrails-induced-Cirrus (CiC) are formed from water vapour, depending on ambient air characteristics and combustion gas mixture characteristics. Contrails are the white cloud-like formations in the sky, which can often be seen in the sky when an aircraft passes by, whereas CiC

is the dispersed variant of the contrail clouds. Both contrails and CiC have a huge impact in terms of the global warming potential, measured in radiative forcing. Therefore, we came up with some alternatives, such as routing and flying on different altitudes, depending on the longitude the aircraft is flying. This is technically possible, as the Flying-V seems to be less heavy with hydrogen when compared to a normal configuration. Water vapour itself has a global warming potential as well, but this is a factor 20 times less as the effects of contrails and CiC. Also, water vapour has a relatively short life cycle.

Overall, hydrogen as a fuel has a more positive effect on the environment when compared to other types of fuel. It would make the Airbus targets and The Paris Agreement within reach.

What are the different challenges to Flying-V?

This question can be looked upon from two different perspectives, one is the perspective of the Flying-V itself. For further research of the Flying-V over 50 research questions are listed and they range from safety aspects, too regulatory and flight dynamics. Many of these topics need time, time to model, test and simulate, to change manufacturing procedures at factories, train pilots to be able to fly with these types of aircraft, but also time to create acceptance within society. After all, this aircraft will be a different experience for everyone involved, from the governmental bodies to manufacturers, to the end-users. You and I will step aboard and sit within the wing of an aircraft. To give a practical example of

why this is also an important aspect: to face the direction of flight, passengers will need to be seated at a certain angle. There are regulations in place to adhere to, but it might also be a different experience for the passenger. All these tiny details are required to be thought of, being tested, made adherent to the regulations.

The other perspective is the possible implementation of hydrogen as a fuel. Stating the Flying-V could potentially fly on hydrogen is one thing, tackling all the relevant challenges for the implementation is another. For instance, will we have enough 'green hydrogen' available to fly sustainably? Green hydrogen is hydrogen created from renewable energy sources. There are other sources for the production of hydrogen, such as fossil fuels. But with these, we will be shifting the problem down the chain, without solving the actual task at hand. Similarly, there are tasks at hand for the production, storage and transport of hydrogen, the whole infrastructure.

To give another challenge ahead, for the implementation of hydrogen the assumption taken was that the fuel cell technologies will develop at a certain rate. To make it more quantifiable: from literature review, we assumed an 8kW/kg output, whereas state-of-the-art fuel cells have an output of 2kW/kg. Challenges like these developments need to be surmounted.

Overall, these developments take time. Hopefully one day, the aviation industry can make that step forward and revolutionise the skies. That would be a big step forward for all of us!

Deep Space for Everyone



With the exploration of our solar system currently being limited to governmental space agencies or large private corporations, researchers in other institutions can have a hard time getting their instruments onboard a spacecraft to gather the data they need. Team Tumbleweed aims to make the Red Planet accessible to research institutions, companies, and researchers who want to collect information from Mars. By designing and building almost 100 of the versatile rovers and launching them to Mars in a swarm, Team Tumbleweed will allow researchers to integrate individual experiments and sensors on the Tumbleweed rover at greatly reduced cost. We spoke with Felix Abel, a Master's student* in Electrical Engineering (track: Signals and Systems) at the TU Delft, about his experience in Team Tumbleweed and the role of space exploration in engineering education.

About Felix

Felix did his Bachelor's in electrical engineering in Germany as a cooperative study with the space branch of Airbus. During that time, he had the chance to do a two-month-long internship at NASA in the USA. He came to the TU Delft to pursue his Master's in Signals & Systems, but found himself missing a practical challenge. This was also when Team Tumbleweed was expanding internationally, especially in Delft. Felix joined the team in November 2019 as one of their only two electrical engineers. His task at the time was to lead a team of electrical

engineers to creating a high-level design of the electrical and electronic system of Team Tumbleweed's wind-driven Mars rover.

How does the Tumbleweed operate?

Like so often in technology, nature works as the perfect model. Inspired by the tumbleweed desert plant carrying over terrestrial planes, the eponymous rovers make use of the strong Martian winds. Precisely arranged sails cross-connect the rover's outer arcs, creating a spherical structure. The Tumbleweeds' design allows them to harness the winds' power as propulsion on their journey across the rocky landscapes and vast deserts of the Red Planet. The mission, however, begins much earlier: The Tumbleweed rovers can be collapsed into discs, thereby minimizing the space they need during launch and transfer atop a rocket. The structure then gets deployed months later in midair, when the rovers are dropped over the surface of Mars. During their descent, the Tumbleweeds unfold to take on their full, spherical shape, about 5 meters in diameter. This enables them to break their fall, acting as their own parachutes, before hitting the ground.

Once landed, the rovers can begin their work. Equipped with a multitude of sensors, the wind carries each Tumbleweed along an individual path across the Martian surface. Along the way, the sensors gather a vast array of data. Aside from covering a basic framework of information

with data on temperature, atmospheric pressure, and imaging, the Tumbleweeds carry out deeper exploration using the sensors integrated by external researchers through a standardized interface. With few boundaries outside the technical requirements, researchers are free to use their space on the Tumbleweed to gather whatever data they may want. Possible applications already determined by Team Tumbleweed's science team include the search for past life, geological and climatic processes on Mars.

What makes Tumbleweed different from legacy rovers?

Current Mars rovers, such as NASA's Perseverance, contribute extremely valuable scientific data. However, such legacy Mars rovers exhibit three big drawbacks. First, they are expensive, costing several billions of euros while only allowing a fraction of the proposed instruments onboard. Secondly, they are risky: A critical fault in the rover can mean the loss of the whole mission. Last but not least, due to their slow speed they can only survey a very small part of the Martian surface. The Tumbleweed rover challenges this prevalent approach: Pairing existing technologies with novel ideas, the wind-driven rovers can be produced in large numbers, decreasing both cost and risk of failure.

Tumbleweed's launch and transfer to Mars is like that of



legacy rovers. The difference is in EDL (Entry, Descent and Landing) – instead of rocket-parachutes systems or airbags, Tumbleweeds act as their own parachutes. And although they will have to sustain the impact and all the tumbling around on the Martian surface, they have more relaxed requirements for the duration of the mission – several months, rather than several years.

Traditionally, landing sites of rovers were chosen to minimize landing risk, but then you miss out some of the most interesting sites on Mars – like mountainous or hazardous terrain. According to Felix, “Something that has happened repeatedly in space exploration is that the most interesting findings were the ones that were not anticipated. And this is one of the most promising aspects about Tumbleweed, that we are not going to this one spot, we are just going to put a hundred rovers on Mars and let them roam.”

What were some of the design challenges you faced?

In 2019, the team had a good Earth-grade prototype in the right shape, but the electronics

were not suitable for space; they couldn’t withstand radiation, temperatures or the forces of launch, nor were they maintenance-free.

“When I joined the team”, recalls Felix, “we started with a blank slate to design an electric and electronic system for a space-grade prototype. Of course in the beginning you progress quickly, it’s very creative because there are lots of open ends, and you need to make assumptions. After that, we spoke to experts at the European Space Agency (ESA) and other space companies and did some requirements engineering (you might be familiar with it from the Systems Engineering course, it’s fun when you do it for real). At that point we had established our system boundaries for different sub-systems, and we could get closer to designing on a schematic level first, then at PCB level, to finally work towards prototypes for the different sub-systems.”

The current approach is a completely unguided system, other than a single-use braking mechanism – for example to respect no-go zones for planetary protection reasons, or to meet other regulatory demands. The

structural team is also still exploring various concepts and learning from their existing prototype, which underwent a wind tunnel test earlier this year.

How do the rovers communicate with Earth?

Existing rovers like Perseverance all use two types of communication: Direct communication from rover to Earth, and relayed communication to Earth via an orbiter in the Martian orbit. These methods use high-gain antennas which can span up to 3m in diameter.

“Our main challenge is that our rover is moving constantly, and we would have a very hard time pointing the antenna. So, we assume that we have to exclusively rely on relayed communication. In that case, the pointing requirements are relaxed because the orbital relay is much closer to the rovers.”

Three high schoolers and a garage

As an organization, Team Tumbleweed had its humble beginnings in 2017 in a garage in Vienna, where three high school students built the initial Tumbleweed rover prototype. Since then, a lot has changed: Team Tumbleweed has designed, built and tested several prototypes, managing to secure support from the ESA by becoming part of its business incubation program.

Meanwhile, the Team has grown into an international and diverse group with 80 members, mainly located in Delft and Vienna. In Delft, the main focus lies on Mission Design, Structural Engineering, Software and Electrical Engineering.

Recognition from industry experts

Team Tumbleweed is part of ESA’s

Business Incubator in Austria. They receive guidance and some financial support, as well as concept validation from external experts. Getting accepted was a decisive moment for the team, considering their humble roots; it gave the team a huge confidence boost and the legitimacy of being accepted by experts.

“I’ve already had a meeting with ESA experts for some specific technical question or a request for information in a specific field,” says Felix, “This is one of the big benefits of being in Team Tumbleweed – you have access to experts and leaders in the field, and you gain a lot of valuable information from discussions with them.”

Who are your competitors?

“Unfortunately, Mars exploration is mostly limited to governmental actors or large companies like SpaceX,” says Felix, “and the reason for that is that deep space exploration (beyond Earth and moon) is expensive and it fails often. Usually, smaller players do not try to compete in this

market, so we’re in a market with relatively high entry barriers. We hope that through our fundamentally different approach we can make it work despite being a small organization. We don’t have this one big, expensive rover that we want to land on Mars – because if that fails, the mission fails – instead we have a swarm of multiple rovers.”

The role of deep space exploration in EEMCS education

As humans, we are curious. We are explorers. Mars is our first candidate to become a multiplanetary species, and our generation is lucky enough to live in one of the most interesting decades for space exploration. If as an engineer you’re looking for the ultimate challenge to apply your knowledge, there are not many things that combine so many demanding aspects as designing a spacecraft for deep space exploration. This is particularly the case for EEMCS-related topics.

“At a young organization like ours, you can really shape the organization and make an

impact. You of course have more responsibility, because your supervisor isn’t keeping a close check on you. But you learn a lot along the way. I have the honour of working with an inspiring leadership team and a lot of passionate and skilled teammates. We have a diverse range of members – people have joined in their last year of high school, but we also have people with 10 years of professional experience who have a day job and work on the rovers on the side.”

“Looking back to when I joined 1.5 years ago and where we are now ... it’s been an incredible journey and the best is yet to come.”

Any advice for other students?

Next to your education, find a topic you are passionate about where you can apply the theory you learn in your studies. Learn from setbacks and keep pushing for your idea. Team Tumbleweed is always looking for TU Delft students passionate about space exploration who want to join the Road to Mars!



Ampère's law and Faraday's law

Lou van der Sluis, Honorary Member Electrotechnische Vereeniging

Ampère's Law is one of the fundamental laws in electromagnetism. It describes the relationship between an electrical current and the magnetic field created by that current. Let me tell you about how Ampère's Law was discovered, explain how it works and how we can make use of it in practice.

In 1820, in the month of July, Hans Christian Ørsted, a Danish physicist, carried out experiments with a Volta pile, an early type battery, that supplies current. Ørsted noticed that a compass needle moved when it came close to current carrying conductors on his workbench.

In those days, the results of physical experiments were shared and discussed in scientific societies and what Ørsted had observed spread quickly over Europe. The Académie in Paris asked André-Marie Ampère to verify Ørsted's findings. So, in the summer of 1820, Ampère repeated the experiment and took it further.

He placed two copper wires in parallel, let an electrical current flow through the wires and discovered that the wires move towards each other when both currents flow in the same direction and move away from each other when the currents flow in opposite direction.

Ampère derived a formula to calculate the forces between current carrying conductors. This force is proportional with the current value and inversely



Our story begins with Hans Christian Ørsted

proportional with the square of the distance between the conductors.

Thanks to Ampère's experimental work we are able to calculate the relation between the current through a conductor and the magnetic field in the space around the conductor. This relationship is known as Ampère's Law: the line integral of the magnetic field vector around a single closed path is equal to the current enclosed.

The magnetic field lines run in circles around the conductor and the magnetic field vector points in the direction that a corkscrew makes when it rotates in the direction of the current flow.

We can also explain why two parallel conductors attract each other when both currents flow in the same direction. In the space between the conductors, the magnetic field lines from the two conductors cancel each other out. Both conductors experience the force of the magnetic field



André-Marie Ampère verifies Ørsted's findings and takes them further.

at the outside and they move towards another.

Ampère also found out that when a straight piece of copper wire is bent in the shape of a turn, the magnetic field lines at the inside add up. By putting a number of turns in series we have a coil and the magnetic field lines are multiplied. The magnetic field can be amplified even more by placing ferromagnetic material inside the coil. A coil with a ferromagnetic core is what we call an electromagnet. Ampère described the results of his experiments in his book *Electricité Dynamique*.

Faraday's law is, together with Ampère's law, one of the fundamental laws in electromagnetism. It describes how a time varying magnetic field can induce an electromagnetic force.

Ørsted's experiment shows that a current flowing through a copper wire exerts a force on a magnet. The news about Ørsted's discovery also reached the Royal



Society in London. The physicist Michael Faraday wondered if also the opposite would work: can a moving magnet also exert a force on current or on a current carrying conductor?

Faraday set up an experiment. He moved a magnet over a copper winding and measured a difference in potential between both ends of the winding. In other words: a time varying magnetic field induces a voltage in the copper winding and the winding becomes in fact a voltage source. But how does this work?

The magnetic field lines passing through a certain surface is called the magnetic flux. The word flux originates from the Latin word fluxus that means flow.

The higher the flux (the more

magnetic field lines passing through the winding) the higher the induced voltage. The induced voltage is also proportional with the change of the magnetic flux over time.

The free electrons inside the copper experience a force. This force is called the Electro Magnetic Force. This force makes the electrons move to one end of the copper winding and here the potential becomes negative. At the other end of the winding the potential becomes positive because the amount of charge inside the winding has not changed.

When we connect a load between the two ends of the copper winding, for instance a lamp or a resistor, a current starts to flow.

This current creates a magnetic field around the winding that opposes the magnetic field of the moving magnet. This phenomenon has been first described by Heinrich Lenz and is since called Lenz' law. When we connect more windings in series they form a coil. The induced voltage of each winding adds up, so a coil with 10 windings has a ten times larger voltage at its terminals as a single winding. We did a similar observation with Ampère's law. The magnetic flux from one winding is multiplied by putting more windings in series to form a coil.

It is a big thing that happens here. By making a special construction of conducting material, such as a copper coil, we are able to manipulate the magnetic field!

Check out four cool animations on electromagnetism that visualize Ampère's and Faraday's laws!



SCAN ME



Karl Schwarzschild

Aniruddh Kulkarni

The epitaph “A physicist who never lost her humanity” is attributed to the respected human being and great physicist Lise Meitner. In the year 1945, Otto Hahn received the Nobel Prize in Chemistry for the discovery of nuclear fission. However, Lise Meitner despite of being associated with the project for the whole of her lifetime, unfortunately did not receive the honor to be the recipient of the Nobel prize.

The world of physics saw a new horizon when Einstein gave the General Theory of Relativity. As impressive it was, most of the world could not understand the gravity of the theory. There was one person who provided the first exact solution to the equations the very same year the concept was introduced. This person was Karl Schwarzschild.

Karl was born on 9th October 1873 in Frankfurt and was eldest of the 6 children. In his childhood, Karl made a small telescope. Noticing his interest, his father introduced young Karl to one of his friends who was a mathematician and owned a private observatory. This was when Karl cultivated interest in astronomy. This interest in astronomy soon developed in Karl and at the age of 16 he published 2 articles which were based on the orbits of double stars. According to observational astronomy a double star is a pair of stars that appear close to each other as viewed from Earth.

In the year 1891, Karl went to University of Strasbourg for 2 years, to study in the domain of experimental astronomy. At the age of 20, Karl went to University of Munich for obtaining his doctorate. His dissertation was on the



application of Poincare's theory of stable configurations of rotating bodies to tidal deformation of moons and Laplace's origin of solar system. During this period Hugo von Seeliger was his supervisory and had very great influence on Karl. During the same period, he developed interferometer which allowed a better separation of double stars with a telescope.

After being awarded doctorate from the University of Munich, Karl further went to work at the Von Kuffner Observatory located in the suburbs of Vienna. This is where Karl started working on photometry. Through his study on photometry, Karl developed photographic plates which he used to determine the apparent brightness of stars i.e., stellar magnitudes. Parallel to his work at the observatory, he also became a

“privatdozent 1” at University of Munich.

The field of observational astronomy had not been developed during that time. Karl’s work on photometry led to many important discoveries. Karl observed that the stellar magnitudes obtained from photographic plates differed from the results tabulated using visual observations. This provided a conclusive proof that the different stellar magnitudes were due to the different colors of stars. Another major observation made was that the range of magnitude change measured by photographic plates was much higher than the range of magnitude change in visual magnitude. This also led to the conclusion that this difference was created due to the different surface temperatures of the stars.

In 1900, Karl discussed the possibility of the universe having a non-Euclidean geometry at the Astronomical Society in Heidelberg. At this point of time Karl got involved in different works other than photometry such as determining the lower limit for the radius of the universe and studying the impact of radiation pressure of the sun. On the basis of assumption that the tail of comets consists of small spherical particles, Karl deduced that the size of the spherical particles present in the tail of comets range between 0.07 and 1.5 microns.

Apart from being a research-

er he was also an extraordinary professor. He served as a professor at University of Gottingen and the director of Observatory. During his time at Gottingen, he worked in the field of electrodynamics and geometrical optics. He measured stellar magnitudes of numerous stars and which he published in the works named “Aktinometrie.”

In the year 1909, Karl left Gottingen and took up the position of director at Astrophysical Observatory in Potsdam. This was one of the most prestigious post for an astronomer. Around this time, Karl was involved in the studies related to spectroscopy. Only few years later in 1914, the world experienced the outbreak of war. During this time, Karl volunteered for military service. He was positioned in France and was responsible for calculating the missile trajectories and was assigned to an artillery unit.

Later during the time of war, Karl moved to Russia. In the year 1915, Albert Einstein had already published the theory of relativity which explained the special theory of relativity which he published 10 years earlier. During Karl’s time in Russia, he wrote one paper which was based on Planck’s quantum theory.

1A recognized teacher at a German University who is not considered a salaried staff.

This explained the Stark effect which is the splitting of spectral lines of hydrogen by an electrical

field which could be proved from the postulates of quantum theory. This was also proved by scientist named P. Epstein at almost the same time in Munich.

The second paper that Karl wrote during his time in Russia presented the exact solution to Einstein’s general gravitational equations giving an understanding of the geometry of space near a point mass. Einstein’s response said, “I had not expected that one could formulate the exact solution of the problem in such a simple way.” This paper later became the basis of study of black holes and showed that bodies of sufficiently large mass would have an escape velocity. But based on Karl’s ideology, black holes only existed as concept and not in the physical universe. The existence of black holes was later proven in 1971 based on the interaction of black holes with the surrounding matter and electromagnetic radiation.

While in Russia Karl contracted a disease called pemphigus. This is a rare autoimmune blistering disease of the skin. During that time, there was no treatment for this disease and after being invalided home in March 1916, he died two months later.

Bachelor Student Column

Maxim Mazurovs

Hi! I'm Maxim Mazurovs, a second-years Bachelor student. Since April 2020, since the first lockdown, I moved to Delft to live in a house with 7 (*student*) housemates. This is really fun and would recommend everyone, because that is what made my time as a student much more fun and the lockdown measures more bearable. Additionally, I'm the secretary of the /Pub, our beautiful faculty bar. Apart from being active in the study association, I'm also a member of the travel student association AEGEE-Delft and the sports association Slopend.

What made you choose this field of study?

In my 4th class of high school, I joined the Open Day at the TU Delft where some explanatory lectures were given about the different studies that were available. I had some studies about which I thought "Yeah, this could be cool", but Electrical Engineering was an option that was by far on top of my list with interesting studies. Maybe, it's because I was inspired by my dad who works with all sorts of security systems or by my granddad who repairs any electronic everyday equipment you can think of for work. Either way, from that moment on I just knew this is the way to go for me. Sure, I looked at some other studies, just to have some sort of back-up plan. However, in the end, this wasn't even necessary.

What made you choose TU Delft?

Well I wanted to go to a Technical University for sure, so the question was which one. To me, Delft was the most appealing. My parents are divorced and live in different cities, Leiden and Zwijndrecht, a village under Rotterdam, so Delft would be the perfect middle for when I would move to here. Myself, I'm born in Enschede, so I've already had enough of the eastern countryside. Ergo, out of Eindhoven, Twente and Delft, the choice was clear. Besides these rational arguments why I chose TU Delft, I also chose this because of something that happened in primary school, because

of which the TU has always been a place I was aspiring to. The last words a friend and I told each other, before our roads drifted apart, were: "Ik zie je binnenkort op de TU Delft!" (*translation: "I'll see you soon at the TU Delft!"*).

Is the BSc. programme exactly what you expected?

I don't think I had a clear expectation of the programme beforehand, however, in terms of difficulty it's quite what I expected. On the one hand, hitherto the programme was hard compared to the ease of high school. On the other hand, both before and whilst the start of the programme, we were warned and informed infinitely many times by literally everyone that it would be hard. Therefore, the road to where I am now wasn't harder than I expected thus far, since my expectations were set very high since the beginning. In terms of content of the programme, it's almost exactly as expected. Yet, there is this one thing, which is one of the most important and exciting parts of the bachelor's programme, but missing nowadays. It's the practicums. Anyhow, no one could ever have expected this would be missing for god knows how long.

What did you find most challenging about your studies?

I think programming was, and still is, one of the most difficult things to master. I haven't had any experience in programming at school at all, so this has been



hard to keep up. Especially if you would look at some students who could practically do what looked like magic at the time. However, I didn't choose Electrical Engineering for nothing – you've got to love the challenges you encounter if you choose this course!

In which field specifically would you like to work after your masters?

Difficult to say, since I'm not even sure which masters I want to choose. If I were to choose one of the four MSc tracks Electrical Engineering has to offer, then 'Electrical Power Engineering' and 'Wireless Communication and Sensing' sound the most interesting to me. Outside these four tracks, the master 'Embedded System' sounds promising

and exciting to me. After the masters, I will stay in the field of my masters, I think. With some luck, this field will give me the chance to contribute something useful and great to the world.

How is the studying from home working with you, in the current situation? Are you still enjoying your current mode of study?

Well, I think I've adapted quite well to this form of studying, however, it's complete trash in my opinion, pardon my French. My way of living has always been in a state of balance which is represented best by the following lyrics: work hard, play hard. However, if you take the 'play' away, then the 'work' can't function properly either. I'm lucky to live in a student's house where I study together with my housemates, so there's at least some of the social pressure we're all used to back in the days to keep studying.

What else keeps you busy besides studying?

Besides studying, as I mentioned earlier, I'm part of three different types of associations in each of which I'm an active member, as much as that is possible nowadays. As /Pub board member, I'd normally be busy scheduling res-

ervations and having the time of my life in the /Pub, however, now it's mostly coordinating the construction of the new bar. Luckily, we're working on a very big, campus-wide online event with all the faculty bars and cafés, so that among other things keeps the excitement in this part-time board year. In addition, I'm a member of the bar committee and the Lustrum committee at AEGEE-Delft and a member of the Extraordinary Activities committee at Slopand.

Are there any suggestions you would like to give your fellow (new) students?

If you're struggling with keeping your concentration on a subject or lecture, I'd recommend trying pomodoro timer. If you haven't heard of it yet, it's an online timer that maximises your productivity by giving you a short break of 5 minutes after every 25 minutes and a long break after 3 of such cycles. In those breaks you do what's totally different than what you're studying right now. This could be some stretching or a workout, shoot some bots in a Call of Duty game together with a housemate or staring intensely at the horizon with some fresh coffee. This pomodoro timer has really helped me to pick up my

studies after doing barely anything when the lockdown began.

If you're struggling with starting with your studies, with getting up from bed early instead of laying in there until lunch, then I'd advise you to form some study days with your housemates or friends via an online platform. The goal is to push each other out of bed and force to stick to some study routine. Moreover, remember: the more you do your best now, the more you can enjoy life and experience the best *twaarschdip* ever whenever it will be possible.

Could you tell us something about a project or any other extra curricular activity that you have done?

There's one extracurricular activity I can tell about, although it will take place only in the next quarter. In Q3, there'll be the possibility for second and older years' students to follow an extracurricular course, namely about machine learning. I will be following this course too and I'm hyped about it, since we will get to learn a lot about machine learning algorithms and its real-world applications and master python whilst doing so. I believe that both things will be very useful for the future.



Master Student Column

Bet Rufas, Natasha Birari

No one will ever accuse me of being much of a writer, but I've always loved putting everything down on paper. Yes, I'm that neurotic post-it freak whose textbooks were covered in a thousand different color-coded notes. Probably not the first person one would go to when in need for an organized reflection article for the master student column. So, it's quite funny that I ended up here trying to properly collect my thoughts and talk about myself and my life as a TU Delft student in a brief text. But, who doesn't love a challenge?

First, let me introduce myself. My name is Bet Rufas and I am a second-year WICOS (Wireless Communication and Sensing) student from Barcelona. I studied technology in high school and went into Telecommunication Engineering, because I had no idea of what I wanted to become in the future, but I knew I liked math. I studied hard and found great interest for engineering and anything that involved problem solving. But this was still too broad for me. I needed to know what exactly I was good at and find



some purpose. So I decided I'd go for a Masters.

I came to TU Delft because WICOS had what looked like the perfect program for me. I would meet people from all over the world, take incredibly interesting classes, and live in one of the most charming countries in the world. It sounded like this was the perfect place for me to finally find my place in engineering. And then Covid became a thing.

Months passed, and lockdowns were ruled. Bars and restaurants closed, and we were banned from campus – not quite the year I'd expected.

I was sure I'd never get any major life breakthroughs from the comfort of my room: I still had no idea what my specialization should be, or what classes to take, even less what I would do with my life. I started feeling a steep downfall in my interest in classes taken (*practically*) in isolation. So I decided to focus on other things to break with the draining routine, and I properly took my mind off of university for the first time in forever.

I'd been searching for satisfaction in academic achievements and looking for that one thing that would be the right fit for me. I'd always assumed it had to be engineering and academia, that was 'what I was good at', so it was easy to believe that the possibilities ended there.

But as it turns out, the possibilities are endless: there is so much more I want to do! I teamed up with friends and focused on creating our first startup. Learnt to design websites and worked on



some projects. I gained interest in digital marketing and built an online business. I attempted to learn Dutch and took courses on philosophy and even learned how to make Instagram filters for fun. I quit my Netflix routine, got back to reading and found time to draw and paint again. I exercised and I found personal growth in many aspects of my life – unrelated to school.

So I recharged, and got back all my motivation: I suddenly felt a huge interest for my classes again. I wanted to combine my interests and work doing a bit of everything. So I talked to professors and looked for an internship that would give me the opportunity to learn and apply my engineering skills onto new projects and take on challenges, and TU Delft was the perfect place to find that.

Its great connection and reputation in the industry really helped me land an internship at NXP where I can apply what I most liked about my classes while getting my feet wet in the industry.

Learn what it's like when engineering and business meet, and how your creativity to find solutions and ideas matter. Where projects have a purpose and what you do will directly benefit society.

Looking back I realize that my first year of classes at TU Delft helped me find the motivation to move towards the field that I want to be a part of, and thanks to its contacts in the industry, I found purpose and motivation to actually build something using the tools I've gained during my studies. Now, don't get me wrong, I still don't know where I'm going, or where I'll end up after graduation, but I can finally say that I've found a good path to follow.



Nuna-11: Dream Solar Car

Interview with Caroline Smulders, member of the Vattenfall Solar Team

Aniruddh Kulkarni, Neil Dani

The future of the world lies with sustainability. In the past century tremendous development has been seen in the automobile sector in terms of vehicle development, transportation reach and the interconnectivity between places. Although this has been extremely beneficial for mankind, there have been several ramifications that cannot be retracted. Hence, for the betterment of the future, several renewable based sources are being developed for various purposes such as transport, energy generation.

For promoting this vision of surviving in a sustainable future,

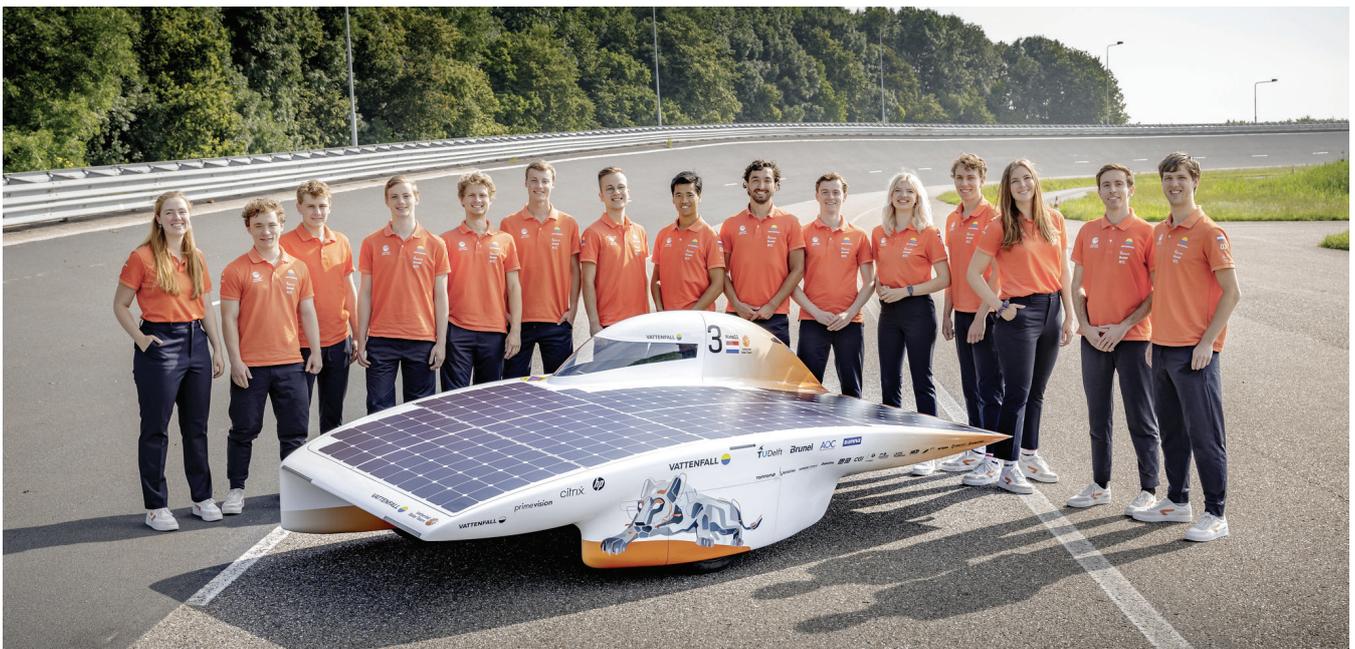
the Maxwell Committee contacted the Vattenfall Solar Team. The discussion on their perspective of a solar car has been presented. The Vattenfall Solar Team (known in the past as Nuon Solar Team) builds solar based race cars. The car is designed to race at the Bridgestone World Solar Challenge, in Australia. We interviewed Caroline Smulders, member of the Vattenfall Solar team to know more about how the team operates, what goes on while designing such a car and how they see the future of the solar cars.

"This is a race of 3000 km from Darwin to Adelaide. So we build

the car based on the design rules of this competition, and strive to have the best car possible."- Caroline Smulders

What is the concept behind such type of car?

We pay attention to the efficiency of the car. We design the car to be as efficient as possible, so we want to have a aerodynamic car (which means less air resistance, so less energy loss) and an efficient electric system (for example, an efficient solar panel and a battery with a high capacity). Our car only uses solar energy in order to race.



Vattenfall Solar Team

What is the current stage of the project?

July 8th we revealed our new car, Nuna11. We started brainstorming about a new design in August 2020, then we started to work out our design in more detail. In the past few months, we have built the car and right now she is ready to be presented to the world! She

Considering the fact that Nuna 11 is a race car, compared to an average sedan what are the standard differences in the design?

The performance efficiency is much higher than an average sedan. For example, our air resistance is only as little as one side mirror of a regular sedan. Our solar car is much more op-

A big decision this year has been on using a 'catamaran' style solar car, or a 'bullet' style, which is more elongated and is completely symmetrical. This was driven by a change in regulations which allowed the use of only 3 wheels instead of 4. All of our big competitors have changed the design to a 'bullet', but Nuna11 is a 'cat-



Nuna 11, The Solar Car

(we always use female pronouns for Nuna) is ready to race, we have already done some tests and driving. As one of our drivers told us, she 'rijdt als een zonnetje' - she is running like a dream.

How is it different from the commercial cars with a similar concept such as Nissan Leaf, Light-year One?

I think our technical design is much more focused on the efficiency of the car, every millimeter counts! We have a similar concept with enhanced efficiencies, not exactly the same basic design.

timized, in order to consume as little energy as possible and to collect and store as much solar energy as possible.

The evolution of the cars are seen to have different shapes from time to time. What is the thought behind the shape of the car?

We always design our car based on the rules of the world championship. These rules change over time. Every year we try to design the most efficient car possible. We have to take a lot of things into consideration and make lots of trade-offs. For example, we need to see if a heavier battery, with more capacity, is worth the extra weight or not.

amaran', which should give us an advantage over the other cars.

What type of PV modules are in these type of vehicles. It is seen that the commercial panels which are used to power a house or loads do not have high efficiency. So what are your views on the PV modules which are used for the car?

We produce the solar modules ourselves. This year, I made modules using 'standard' silicon solar cells. These are interdigitated back contact cells, which means that there are no busbars on the front surface of the cells. Since the car has a very strange shape to put a solar panel on, we indeed

make flexible modules. A module is made up of different components, it is like a sandwich: backsheet - encapsulant - solar cells - encapsulant - topsheet. The encapsulant is sort of a glue which holds everything together. We use our own topsheet, which is a topsheet with a special structure. This makes our modules (that is what we call the different parts of the panel) more efficient.

In the past we have also used GaAs cells, which are used in space for example. These cells are toxic, so we do not use them anymore.

How is the selection of machine affected considering the vehicle will be operating on solar. Most of the upcoming EV's are using induction or permanent magnet based machine for traction. Is it the same for Nuna 11?

We use an in-wheel motor. The machine is not only based on how much the solar panel generates, but it is a bit more complex trade-off where we have to take lots of things into account, such as the route we are driving (hills), the solar panel, the battery, and more. But the solar panel is part of it, yes.

The solar technology emerging in the automobile industry is nascent at the moment. Still being a team who is actively working in this field, how do you see the vehicle market will be for the solar vehicles?

It is definitely hard to make predictions for the future. I think solar can help the popularity of electric cars. A problem right now is the range of most electric cars compared to gasoline cars. If you have a solar panel on your

roof, such as Lightyear has, you can have a larger range. I hope this will be more standard in the future, so it becomes more appealing to drive an electric car. There are a lot of innovations in the field in order to make these cars more and more efficient, so I think this helps the energy transition.



Witteveen + Bos

Sander van Gameren MSc., Jelle Tams MSc.

1. Introduction

The demand for energy in our society will only increase in the coming years, as well as the desire to lessen our dependency on fossil fuels. To realize this change, significant adaptations are required to the electricity grid. Concurrently the Dutch government aims to start more house construction projects, to make housing more affordable for starters. Because some housing projects are constructed at the edge of cities, new houses might be built close to existing electrical substations and power lines. A substation that is near a residential area might cause adverse effects for the inhabitants. Not

only will the electrical currents resulting from the substation affect the nearby piping, but also the exposure to magnetic fields can adversely affect children [1]. Therefore, when a neighborhood is constructed in proximity of a substation or power pylons, the electromagnetic influence on the neighborhood of the substation must be investigated.

In this article a hypothetical case will be investigated where a new substation must be build close to a residential area and a farm. This situation is shown in Figure 1. There are many ways the electromagnetics of the substation can influence the surrounding

area. However in this article we will solely focus on the inductive influence on the nearby piping of the currents passing through the power lines and the substation. This gives the reader insight on how work is executed in Witteveen+Bos regarding such cases. Witteveen+Bos delivers consultancy services regarding high-voltage systems, like power substations. With investigations such as described in this article, Witteveen+Bos contributes to better environment for man and nature.

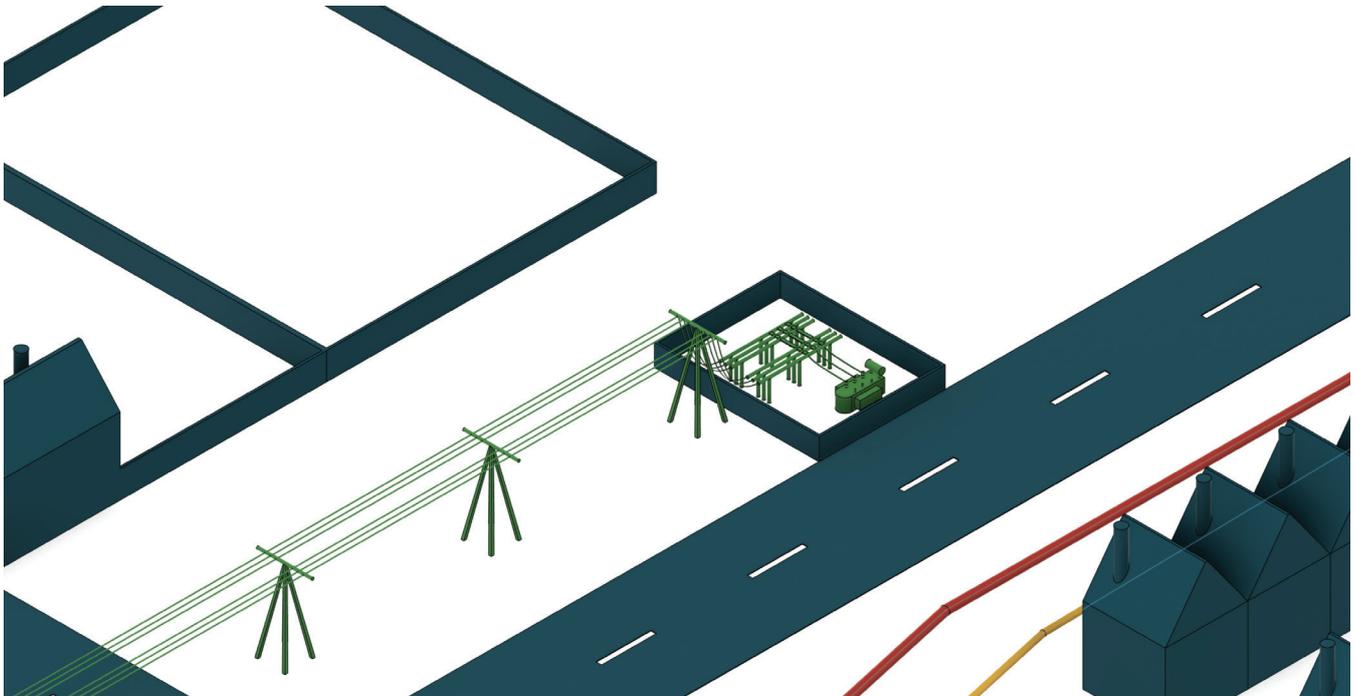


Figure 1: The to-be-build substation, positioned roughly in the center of the figure

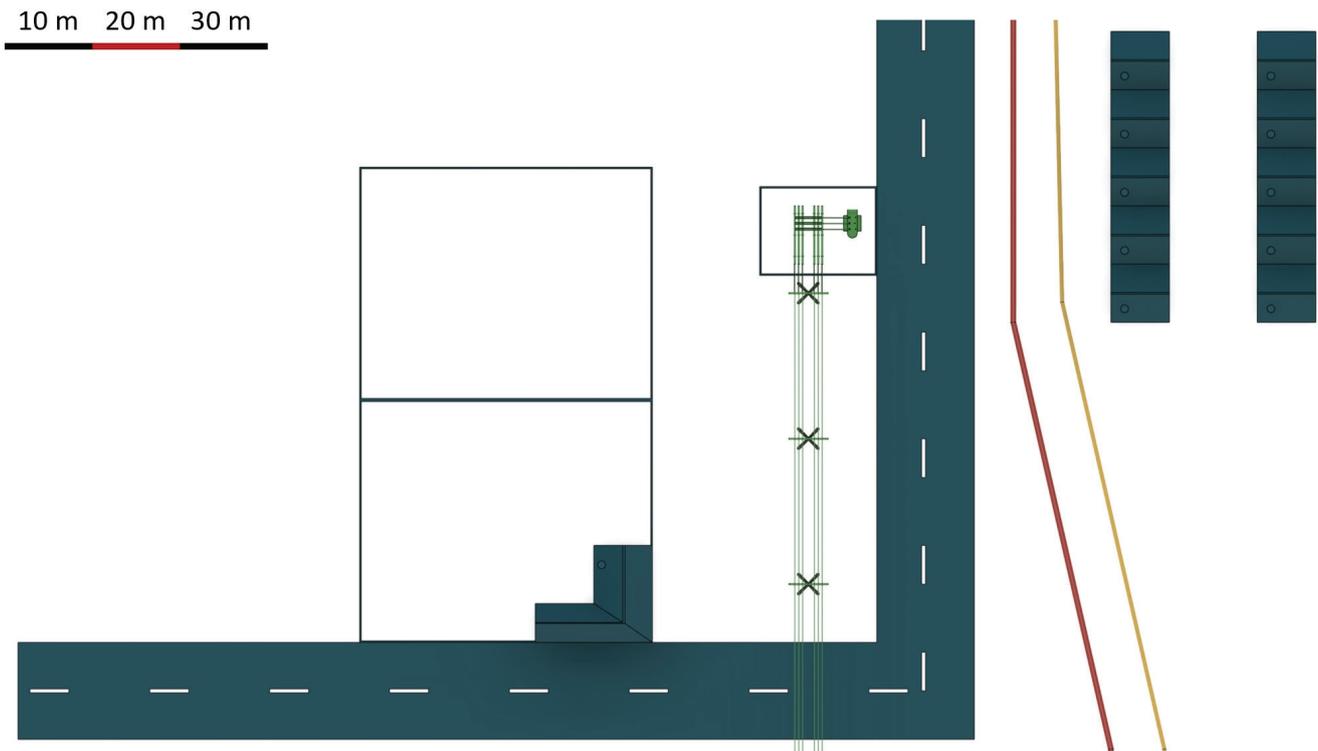


Figure 2: A top view of the cables in proximity with substations and power pylons

2. Approach to investigating inductive influence

In the hypothetical case, Witteveen+Bos is asked to investigate if the placement of the substation and the power pylons, including power cables, has a negative inductive influence on the surrounding environment. The approach selected for solving this case is to work from a crude approximate and refine when required.

Step 1 Distance and the parallel run of power lines

In the first step we investigate if there are any pipes or cables nearby the power station and lines that can be inductively influenced. After investigation it is shown that a gas pipe and a data cable are near the power lines. This situation is depicted in figure 2.

The larger the distance between the high voltage systems and piping, the smaller the inductive

Influence will be. Also, the longer the distance that the high voltage lines and the pipes run in parallel, the larger the inductive influence will be.

Based on the distance between pipe and power lines and the length of the parallel run between pipe and line an initial estimate can be made of the inductive influence, which tells us if further investigation is required. To do so, figure 2 of norm 'NEN 3654' is used. This figure is shown in Figure 3 below.

Step 2 Unity check

In this step more details are considered to determine if there is an unacceptable amount of inductive influence. This is done through the Unity Check (UC):

$$UC_I = l \times K_1 \times [\log(K_2 - \log(a))],$$

Where *l* is the length of the parallel run of the lines (in km), *a* the heart-to-heart distance between the pipe and the high voltage line

measured horizontally in meters, *K₁* and *K₂* are constants dictated by NEN 3654.

For our case, the subtraction $\log(K_2) - \log(a)$ has a value > 1 , and the product $l \times K_1$ has a value > 1 . This means that $UC_I > 1$. This means that the configuration of high voltage lines and pipes does not pass the unity check and we need to take an extra step.

Step 3 Adjusting the unity check

Our UC-value was larger than one, and therefore a refinement of the UC-calculation is necessary. In this step, the values of *K₁* and *K₂* are adjusted to be situation specific. For example, *K₂* is in part dependent on the resistivity of the earth. In step 2 this resistivity might be overestimated. On-site investigation and measurements can result in situation specific values for *K₁* and *K₂*.

After the adjustments, it seems that the UC-value is still larger than one, a next step is necessary.

Step 4 Refined calculations

The value of the UC being larger than one suggests that an unacceptable amount of inductive influence is exerted from the high voltage lines on the gas pipe and the data cable. In this step we calculate from the geometry and Carson's equations what the induced voltages are.

Then, the calculated voltages are compared with the current standards and regulations, and we determine if the design of the transformer station with the high voltage line in combination with the data cable and gas pipe complies with the law and regulations.

Continuation

If the voltages calculated in the prior phase do not comply with law and regulations, then the de-

sign of the station and high voltage lines needs to be adjusted to prevent unacceptable inductive influences. Witteveen+Bos will collaborate with the client to get to the root of the issue and start a discovery process on redesigning the station.

3. Conclusion

The current growth in energy demand and the city limits makes for situations that can create unacceptable electromagnetic influence because of a limited construction space for both housing and electrical infrastructure. Witteveen+Bos, in collaboration with the parties involved, is investigating whether inadmissible influencing may be taking place and advises on possible alternatives where necessary. The ultimate goal is that we work to-

gether on a safe environment in which we give space to the growing energy demand in combination with growing city limits.

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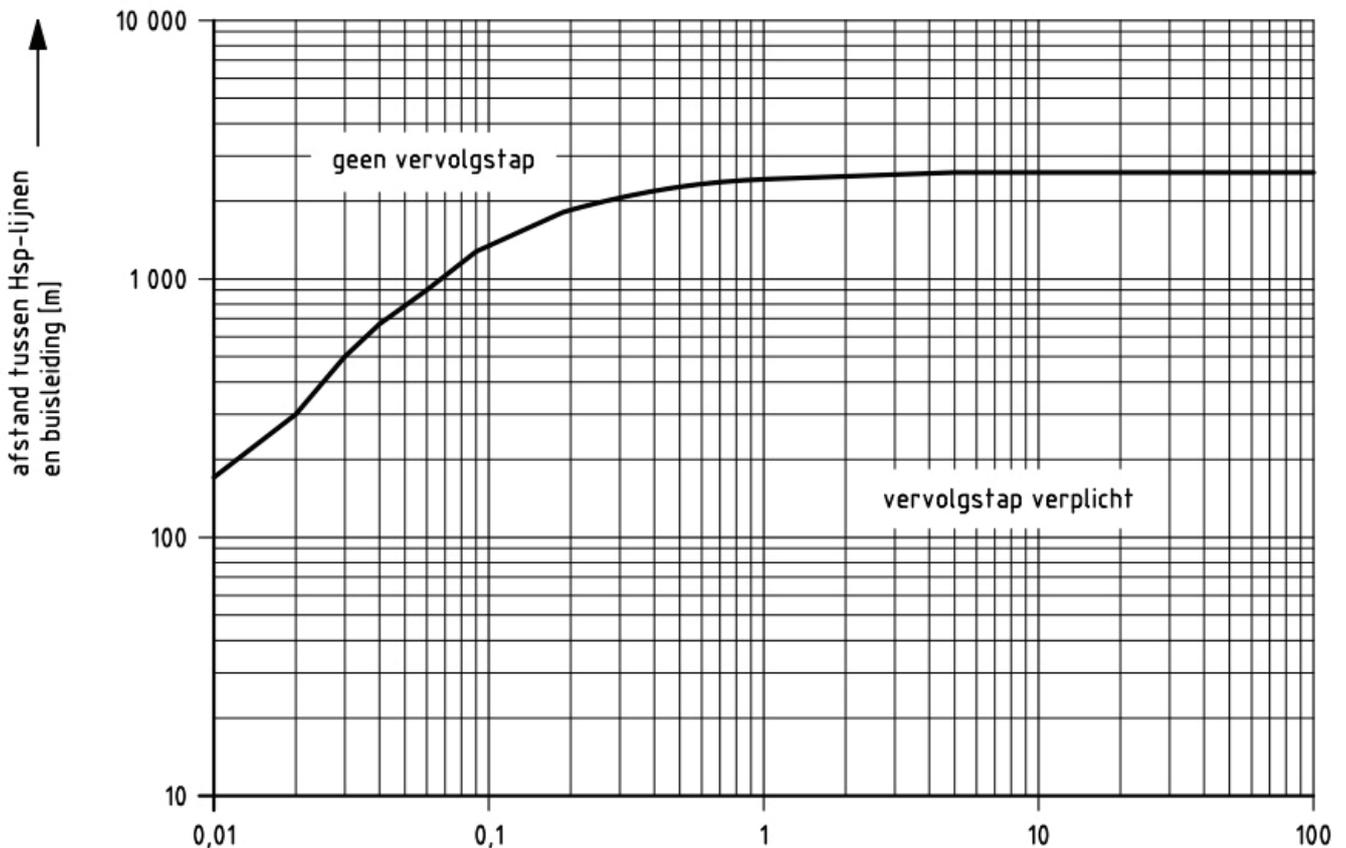


Figure 3: figure 2 from NEN 3654. The figure shows when further investigation is required

