**Inside View**
Nanostructures of Functional Oxides

**Theorist**
Where are they?

**Francken Abroad**
Paul's adventures in Uppsala, Sweden

# Francken Vrij

## Intelligence

22.3 Intelligence

TMC

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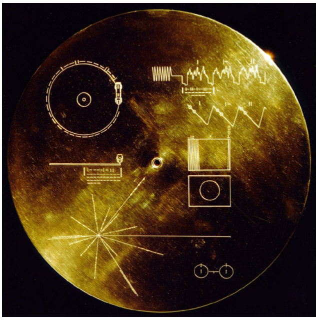
# Edition 22.3





# Colophon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## Editorial

The theme of this Francken Vrij is 'Intelligence'. You could wonder what connection is between Physics and intelligence. However, both in Theoretical and Applied Physics intelligence is a hot topic. In the Theorist, Jasper has written about the search for extraterrestrial life and professor Noheda tells about intelligent materials in Inside View. This edition will be my last edition as editor in chief. Not only I will leave the editorial board, but also Paul, Kathinka, Gerjan and Steven will leave. I hope the new editorial board will have as much fun as we did making the Francken Vrij. But for now, enjoy reading this new Francken Vrij and have a nice summer!


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# Chair's Preface

By Kathinka Frieswijk

**This May, Google** introduced Duplex, an Artificial Intelligence assistant that can book appointments for you at your local tapas restaurant. The interesting part is that Duplex seems completely indistinguishable from a human, using pauses, *umm*'s and *mmm-hmm's* in sentences like the next person. Thus, if the voice recordings presented by Google are real, Duplex would easily pass the Turing test.

This technology would bring upon a new era for phone scammers. Scammers can relax and sleep away at Random Beach, while their AI slaves bring in the dough, guiltlessly extorting money from sweet little grandmas. Scamming paradise in a nutshell.
But far more importantly, if Idun happens to *bras* (i.e. steal) the Francken clock again, you can completely upgrade your gameplay. Besides writing a few lines of code that enable you to automatically email them every single minute to ask what time it is, you can now have an AI assistant call them every minute of the day as well. Very irritating, and very much approved by me.

Since it is almost time to pass the baton as chair, I'd like to thank everyone for making this board year absolutely brilliant. In particular, I'm eternally grateful to my fellow board members Anna Kenbeek, Arjen Kramer, Su-Elle Kamps and Mark Redeman, who had to put up with me for a year. As Pjotr, the faulty Bomb Disposal Robot, would say - 'it's been a blast!'.

Lastly, as a side note, it would be interesting to let an artificial intelligence system write the 'chair's preface' and see whether it would ace the Turing test. Or maybe I already did that? Umm…

# News of the Association

By Anna Kenbeek

**This is already** the last time I have the honour to write about the news of the association. After this edition, I will have to bother my friends again about Francken, instead of having the Francken Vrij as an excuse to dwell on past and coming activities. The past months have been full of activities, including a few of the most special activities of the year. The board 'Hè Watt?' concluded their board year with a great period.

**King's Mark(et) Borrel**
Not only was this event planned on King's night, it also fell on the birthday of our commissioner of external relations, Mark. This was enough reason to organise the King's Mark(et) Borrel, where you could trade certain beer brands and celebrate the birthdays of first Mark and then the king. While drinking orange coloured beer and making loss on our purchased beer brand, we had an awesome night.

### Symposium: power from within

This year's symposium was again a great succes. Speakers from all over the country and even from France came to the Van Swinderenhuys in Groningen to tell us something about nuclear power. The topics concerned different ways of energy supply, fusion, fission and use of nuclear properties of atoms in the medical world, such as proton therapy. Also there was time for some delicious lunch, including *kroketten*, and afterwards there were free drinks. With Prof. dr. Steven Hoekstra as the chair for the day, it was an interesting and enjoyable day.


### Hitchhiking competition

Seven teams of two were ready to compete on Friday the 11th of May: the challenge was to hitchhike to Gent, Belgium, as fast as possible. No extensive preparation could be done, because the destination was announced just in the morning. Nonetheless, one team wore pink dungarees and other teams had some useful tips and tricks in mind. The first two teams were really close and the first team had to take only two rides. The last team was many hours faster than the last team of the competition of last year, going to Lille. One team was also hitchhiking back to Groningen and was faster than the others taking the train. It all went quite well and all participants met several funny or interesting people. We had a nice weekend in Gent, where we visited an old castle and did a beer tasting in the local Stadsbrouwerij Gruut.

### Lunch Lecture by DEMCON

On Wednesday May 16, a lunch lecture was given by DEMCON, a high-end technology supplier of products and systems. Ludo Cornelissen, a former PhD-student in the research group of Bart van Wees, talked about some projects he was working on. There was free lunch and it was a most interesting lecture.

### Members weekend

At the moment of writing, it was only a week ago that 40 Francken members left to the destination of good old *sjaars*-memories. The second members weekend of this year took place in Bakkeveen, just as many editions of Pienter camp did. This time we didn't have to go by bike and get up early, even though some participants still chose to do so. Another difference was the inflatable pools we brought. It took a while to fill them, using many buckets, but then we had enough time to relax in the water, enjoy the warm weather and annoy others by shooting with water guns all the time. On Saturday afternoon, the committee took us to a midget golf course. That evening, a beer olympics was organised, including a beer mile, beer pong and some other games that I do not know the name of. We had a fantastic weekend.

**Buixie to Portugal**

On the 14th of April, 27 Francken members were ready to depart from Schiphol to Portugal for the most extended - and my favourite - activity of the year: the foreign excursion. All suited up, we investigated the field of Applied Physics in Porto, Coimbra and Lisbon. Besides this, we also got to see some splendid (cultural) highlights. Some of these were: a Port tour, visiting the picturesque castles of Sintra, the old university of Coimbra and jumping into the ocean. Also, we had excursions to universities and companies and saw a fusion reactor, an amazing hologram, a tiny company developing mosquito-repellants and of course several scanning electron microscopes. We did many more things until the 22nd of April, and I could write about it for pages, but it is better to just leave that for the final report by the committee. It was a great foreign excursion!

# Meet the New Board

**Joris Doting**

Dear members of T.F.V. 'Professor Francken' and other interested individuals, my name is Joris and I'll hopefully be the new president of our association. I've been studying Mathematics in Groningen for three years now and might well be here for quite some time, since my "studying" also consists of a lot of *klaverjassen*, Francken activities, and *borrels*. What you might not know is that I have been in Groningen much longer. I was born in Deventer, but moved here when I was three years old. As such, I know the city quite well. Likewise, I've been sitting in the Francken room almost daily for some years already now, and played active roles in several committees. It has been just over two years of organising *borrels* with the Borrelcie, the Rocket Science symposium in 2017 with the Sympcie and this year's awesome foreign excursion to Portugal with the Buixie. This coming year I hope to be able to apply all this to make it an amazing year for T.F.V. 'Professor Francken' and all its members (and *donateurs*!) together with the rest of the 34$^{th}$ (candidate) board!

**Chantal Kool**

Dear reader, I am very happy to have been given the chance to serve you as the secretary of the 34$^{th}$ board of our beautiful association. But who is that girl that dropped by in 2017-2018 to help organise the Buixie and previously baked some cakes when the Taartcie still officially existed?
My name is Chantal Kool (but I also listen to Chantie, Kool, Bloemkool, Kooltje,…), 22 years old and a master's student in Mathematics. As a person of many interests you can always find me busy with way too many things besides studying including: playing the guitar, acting, working, doing sports (if I feel that it's time to lose weight again) or drinking red wine (where the last option can be combined with any of the aforementioned). Besides this, I am also famous for my *keuzestress*, just ask me once which studies I considered before choosing my bachelor and master. But what is an introduction without random facts? (Just an ordinary introduction, yes you're right). So here you go: I love the UK, alpacas, technology, minions and have gaming as a guilty pleasure.

### Bradley Spronk

L.S. (*Lieve Schatjes*),

I hope most of you know me: Braadslee. But for those who don't, or those who want to know more about me, I have about 200 words to entertain you.

My position next year, hopefully, will be the only position anyone cares about: treasurer. This function is close to my heart, as I know how to manage money. For instance, I started a fundraiser to colour my hair and ending up paying half myself, because I didn't realize it would have to be dyed twice. Buixie'v(ó\al)! Another thing I've done to show that I'm a good treasurer is eating just *frikandellen*, mayonnaise, and salt for 3 months in order to be able to buy a HTC Vive. But enough about me, let's talk about my personal life. I'm now doing my bachelor Theoretical Physics, but also have a strong interest in mathematics, astronomy, programming, Pokémon Go, and drinking *pils*. Next year, I'll merge my body and soul with T.F.V. 'Professor Francken', which I am proud of. I hope to give the association what it deserves and make most of you content. I expect to see a lot of you this year and let's play a game of *klaverjas*! *Le'âh*.

### Leon Trustam

Hello *mooie gekken*. My name is Leon Trustram and I'm the candidate commissioner of external relations and education of our amazing association. I was born and raised in Leeuwarden. Last year I got my bachelor's degree in Astronomy and right now I'm a master student in Energy & Environment. In my free time I like to play poker, go to music festivals/concerts and travel the world as much as money allows. During my final year of the bachelor I had 5 months in which I had no courses and no projects. During this time I visited New Zealand, Australia and some great countries in Asia where I found a new hobby in scuba diving. Next year I hope to be traveling to many cool new and old companies, making contacts and hopefully collecting a lot of money we can use to make university life a little more interesting for you guys. I'm looking forward to making next year awesome at Francken by organising amazing and interesting events and I hope to acquire a lot of money next year so we can make these events as great as always.

**Jeanne van Zuilen**

Almost two years ago, I left my favourite beer behind and came to Groningen to study Applied Physics. I soon found T.F.V. 'Professor Francken' and joined the Sjaarcie while eating a green tosti. Ever since, I can be found in the Francken room pretty much every day asking if you are already coming to the next Fraccie activity. By the time you are reading this, I hope to have been promoted from commisioner of promotion of the Fraccie to commisioner of internal relations of the board of this beatiful association. Before moving in to the Francken room, I will try to introduce myself.

I am both clumsy and handy. I hear you thinking 'How?', well, I have destroyed so many objects by now, I can now fix them as well (but only on *TN-vrijdag*). I collect Tic-Tac boxes, am scared of stairs where you can look through the steps (like in Aletta Jacobshal), enjoy building furniture from IKEA, and will always prefer Grolsch over any other beer. I hope to see you all in the Francken room during activities, borrels, or any other day this year. I am sure it will be a fantastic year! *Hoi*.

*'Statisch', the thirty-fourth board of T.F.V. 'Professor Francken'.*

# Life after Francken

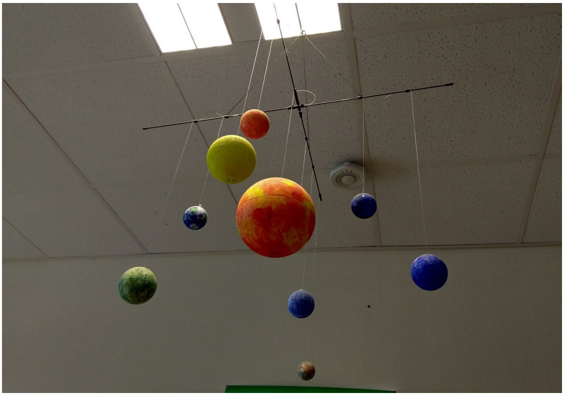
By Maaike van Egmond (Maaike Wiltjer)

**During my first** year, I was already an active member at Francken. At the end of my first study year in 2003, I formed the board of Francken with Marc de Boer, Teun Koeman and Hedde van Hoorn. I also enjoyed many hours in the Francken room playing *klaverjassen* and I took part in several great committees, like the Sympcie, Bincie, and the Foxxie (nowadays known as the Fraccie, the activity committee, red.).

I graduated from the University of Groningen with a bachelor's and master's degree in Physics, and during my master's I mainly focused on topics of environmental physics. At the end of my master's degree in Physics, I was still looking for a job that suited me. Within my circle of friends there are some teachers and they pointed out that there is a great shortage of physics teachers. So I visited two different schools at the time to get an impression of working with young people and what the teacher's work involves. It has given me a good impression of the interaction between teacher and student/class. I was immediately enthusiastic about teaching so I started to follow a post-master at the University of Groningen for education.

At first I followed a 5-month internship in which I was coached by an experienced teacher and gave a number of lessons so that I got used to the interaction with the class. Then I entered my LIO year (LIO = teacher in training), where I was responsible for a number of classes as a teacher. I started by learning to present in front of the class and maintain a peaceful environment in the classroom. Furthermore, lots of attention

*Figure 1: a non-realistic model of the solar system made by a third grader.*



is paid to the didactic skills, such as transferring the curriculum and tackling a problem. If these skills are well developed, you can focus on paying attention to the personal interaction with the students, for example by chatting about the students' interests.

During my postmaster I got a first degree as a physics teacher, but besides physics I also teach NLT. NLT stands for Nature, Life and Technology and it is an interdisciplinary course with influences from lot of beta subjects and it is only for higher classes of HAVO and VWO. During the lessons, a connection is made between, for example, physics and chemistry. In other lessons they are delving into physics subjects such as fusion or measurements of the universe. In addition to the combination of the beta subjects, the teaching methods are not standard. Students must learn the material mostly by themselves and the assessment includes assignments, practicals, tests, posters, designs, etc. This ensures that it is a nice change from a day otherwise spent listening to the students, but also as a teacher it's a different way of teaching and interacting with the students.

A day as a teacher is never the same. On average, I give five lessons a day and that can be a mix from HAVO 3 to VWO 6, with the subjects physics and NLT. During the lesson you are a hostess, presenter, actor, didacticist and pedagogue. I start a lesson by welcoming the students and by taking time for some small talk with the students until everyone is ready to start the lesson. A typical physics lesson consists mainly of discussing homework, repeating the material followed by new explanations and if there is still time left, the students can

work on the new homework. Often the explanation goes through a interactive conversation, in which I ask the students questions to which they know the answers, and I subsequently expand their knowledge.
In addition to the lessons, almost every teacher is also a mentor. A mentor is the first person to speak to a student about school matters and, if necessary, maintains contact with the parents/caretakers. This gives you intensive contact with some students. This also means that you eat out, or do something similar, with the mentor class a few times a year.

Teaching is a core task and the lessons have to be prepared so that they run smoothly. But in addition, the teaching profession also consists of making tests and assignments, and a lot of correction work. And as with every employer there are meetings about the course of the school and report meetings with discussions about students.

Now the goal of this beautiful profession is of course to get the student ready for the university or HBO and to check whether the students have gathered enough knowledge. Furthermore, school examinations and a central exam are taken. The VWO exams have just been written during the writing of this piece. The central exams have changed in content about three years ago. The subject of quantum world and astrophysics is added and electromagnetism is back. The questions on the exams are based on the context. There are more questions about explaining the knowledge and fewer questions with calculations. In the 2018 exam, there was a nice question about quantum tunneling and the use of Kirchhoff's laws.

*If you are curious whether you still have it in you, please visit https://www.examenblad.nl/examen/natuurkunde-vwo-2/2018/vwo.*

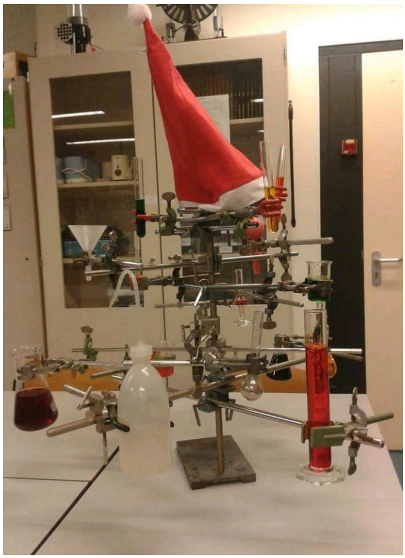


*Figure 2: Christmas tree in chemistry style.*

# Francken Abroad

By Paul Wijnbergen

**As I was** asked to write an article for the ‘Francken Abroad’, I was a bit surprised at first. I have been in Sweden for three months, but in the near history many Francken members have been there before me. Whereas Casper Dijkstra and Jorien van Dulken have been in Stockholm, Marten Koopmans in Linköping, I did my internship at the Uppsala University in Uppsala.

Uppsala is a small city with approximately 140.000 inhabitants about a hundred kilometres north of Stockholm. It’s about twenty minutes by train from the airport Arlanda and forty minutes by bus. The skyline of the city consists of the two towers of the cathedral and the castle on the hill as can be seen in Figure 1. Besides these two touristic buildings, the city centre contains many buildings with a typical Swedish architecture along the river. At the northern outskirts of Uppsala one can find the hills, known as Gammla Uppsala, where, as it's told, some Swedish kings are buried. If one is ever in Uppsala it's worth it to visit this place.

That should be enough about the city itself. Although the city is small, the university is rather large and does quite well in the rankings. In the degree Applied Mathematics there is also an obligatory internship, but of 15 ECTS and hence I thought that it was a good idea to do my internship at the Department of Signals and Systems over there. The supervisor of my thesis had an acquaintance in Uppsala and after two or three emails and a Skype meeting my internship was settled. A few weeks later I had been offered a room in Flogsta for 4300SEK (about 430€) per month via the housing office and I only had to book my flight.

Flogsta is the neighbourhood about twenty minutes by bike from the city centre, where most students live. It consists of approximately fifteen identical flats inspired by the Sovjet architecture. Each floor of the flat has two corridors with ten rooms and one shared kitchen. If you are lucky, the kitchen is usually clean, if not, then it is gross. I was rather lucky, for I had great corridor mates.

If one is tired of studying one can relax every weekend at a corridor party to be found in several flats every weekend. These parties are announced via Facebook, but one can also simply take a stroll at night on a Saturday to locate the music somewhere. Since these parties attract a lot of people and people mainly drink, they tend to get noisy. Make sure you buy your alcohol on time, if you go. Regular beer can only be bought at the government store 'System Bolaget', which closes at 15:00 on Saturdays. However, when you are too busy for a party and you are very frustrated, you can scream it out every day at ten o'clock in the evening. This is the famous 'Flogsta scream' and this phenomenon even has its own Wikipedia page.

The rest of the student life takes place in the so-called student Nations. There are thirteen student Nations, each having the name of a region in Sweden. As an international student one obviously doesn't care about that and you just join one. One can join these nations any time of the year and if you are a member of one nation, you have access to all other nations as well. Each nation has its own building and own bar, where one can have a drink and a burger for a reasonable price. For a student, these are often the only place where one can afford a drink at all, since anywhere else in town alcohol is extremely expensive. Each nation has its own activities, like club, dinners and even some sports which are accessible for all other nation members too. If one is studying in Uppsala, nation membership is a

Figure 1
An overview of Uppsala

must, because besides these nations, there's nothing much in the city for students.

When I arrived in Uppsala on the last day of February it was about as cold there as it was in the Netherlands, but with a lot more snow. The streets were frozen and almost empty. During winter, Swedish life is mainly inside, where it is warm and cosy. At first I thought I would enjoy the cold and icy winter, but after a few days I was done with the ice. Almost falling every five steps and not feeling your hand or ears is not pleasant at all.
Despite the cold and ice, most people in Uppsala travel by bike and so did I. However, every journey by bike becomes an adventure during winter. My house was twenty minutes away from the laboratory where I needed to be every day, so I was happy when spring arrived. When the sun is shining, all Swedish life is more on the outside and the parks are filled with people, just like the Noorderplantsoen. There are lakes around Uppsala to hang out and of course one can take a day off and go to the capital Stockholm. If one has the time, it is also worth taking the boat to Tallin in Estonia. There is a lot to enjoy abroad, so besides the experience of the internship, one does not need to get bored. The international community in Sweden is accessible and hence one will meet new people in no time.

Although I mentioned that I did my 'internship', it turned out to be more of a small thesis than an internship, but nevertheless it was still much more applied than what I was used to in Groningen. The topic I studied was in the field of control theory, which is introduced to Engineering Physicists in the course Control Engineering. It deals with mathematical models of physical systems. Examples of such systems are LRI circuits, mass-spring systems or vehicle models.

The main idea in control theory is that we would like to control the system. Think of maintaining a frequency in a circuit or having a vehicle driving at the same velocity. In the classical theory, it is assumed that information or measurements are never lost in the whole control process. When one is using a wired communication link, this is a fair assumption. When one is using a wireless communication link, information does get lost. A Wifi signal or Bluetooth connection is never perfect. Therefore controllers with wireless communication systems are studied in Uppsala.

When using systems theory for continuous time systems it is very hard to deal with failing communication. If one however uses


Lake Ekoln

$$\Sigma = \begin{cases} x_{k+1} & = Ax_k + Bu_k, \\ y_k & = Cx_k, \end{cases}$$

discrete time systems, it becomes very easy. If one considers a discrete time system, one can model a communication failure at time step $k$ by having zero input at that time step. As the system is not controlled perfectly, because the 'wrong' input is applied, a controller has to 'work harder' when packages do arrive. In general it takes more control cost, e.g. energy, to control the system as more communication fails. This can be seen in an example simulation in Figure 2. If one has too much communication failure it can happen that the system becomes unstable, despite the fact that the controller is designed to stabilize the system. This results in infinite control cost.

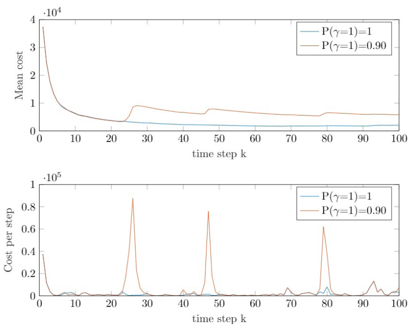



*Figure 2: The mean cost and cost per step for different information arrival probabilitiess.*

These plots show that it is worth improving the signal strength of a transmitter. If a signal is transmitted with a lot of energy, it is more likely to arrive at the desired location. Taking the energy needed for the data transmission into account as control cost, there is a trade-off in how much energy one should use for transmitting the data. The difference between having a 100% and 99.9% arrival probability with a transmitter takes probably a lot more energy than compensating this 0.1% information loss with the controller. The mathematical goal is now to find necessary and sufficient conditions on this trade-off, given a system. So far we have been dealing with a single system. My supervisor in Uppsala, however, had some ideas on extending this theory to a network of systems. In a network, one has measurements at several places and there are several information transmitters. This complicates the matter a lot and there are a lot of questions yet to be answered in this field. Therefore, this was the topic concerning my internship in Uppsala.

In conclusion I can say that I had a great time in Uppsala. I can recommend everyone to go abroad at least once in their student career. If one decides to go to Sweden, I would recommend to go in the spring semester, for the summer is much more enjoyable than the winter.

# Intelligent Materials

By prof. dr. Beatriz Noheda, Professor of Functional Nanomaterials

In the **"Nanostructures** of Functional Oxides" (FUN) group within the Zernike Institute for Advanced Materials, we develop novel materials for future electronics. This comprises materials for memory applications (ferroelectrics and multiferroics), for energy harvesting (piezoelectrics) and, since recently, also materials for adaptable electronics or neuromorphic computing (memristors).

**Why?**

What all these applications have in common is that they crucially rely, as their key elements, on materials that respond strongly to electric fields. Even though, in some cases, the design of the device itself can be as important as the material (as in piezoelectric energy harvesting devices), in general the improvement of the materials physical responses is key to determine the overall device performance. And because, nowadays, progress in microelectronics naturally pushes science to overcome existing limitations towards further miniaturization, it is part of the game that, together with the materials synthesis, we use a variety of techniques that allow a glance into the nanometer scale. Thus, a strong materials science component and the ultimate control of the electromagnetic fields inside these materials at the nanoscale is essential for the development of novel electronic components and it is also the core focus of our group activities.

What all these solid-state materials have in common is that they are wide band-gap semiconductors or insulators in which internal electric fields can be built to control (tune or switch) the physical responses. These responses can be the electrical polarization (in ferroelectrics), the magnetization (in multiferroics), the deformation (in piezoelectrics) or the resistivity (in so-called Mott insulators or in memristors). A good strategy to obtain significantly enhanced responses is to search for phase transitions and critical points, as it is well known that the particular susceptibilities (second derivative of the free energy with respect to the particular external parameter that can be tuned) are enhanced at the phase transitions and, very significantly, at the critical points (where theory predicts susceptibilities to diverge). The challenge here is that temperature-induced phase transitions are not useful in devices, for which temperature stability is of prime importance.

Most materials with the above-mentioned characteristics are oxides and, thus, our main expertise is on complex and simple oxides. Many of them combine several of the properties that we are after, making them multifunctional. For example, a piezoelectric material (which deforms under electric field or polarizes under stress) does not need be ferroelectric (display spontaneous and switchable polarization) but the best piezoelectric responses are those of materials that are also ferroelectric, and thus, for piezoelectric applications, ferroelectrics are typically used. In addition, ferroelectrics are spontaneously polarized and, thus, in a device geometry, they provide surface charges at the interface with the electrodes. This modifies the electronic potential of the semiconductor and changes the contact potential with the electrode, changing the barrier for electron transport. Therefore, by switching the electrical polarization with an electric field, one also changes the conductivity through the device (so-called ferroelectric resistive switching). In this way, by applying increasing values of the bias voltage below the overall switching voltage, we are able to sequentially switch the polarization of increasing volume fractions and attain different resistance state (thus, a memristive device).

These materials are known as intelligent or smart because they can adapt to changes in the environment, like living systems; the same piezoelectric material can sense vibrations in the environment (as pressure waves), producing an electrical signal that is proportional to those vibrations. The device can then produce the exact opposite electrical signal and apply it to the same piezo, which will deform exactly compensating the external vibrations. This is the working principle of vibration dampers used in helicopter blades, cars, downhill skis or even tennis racquets and it is just an example on how ferro/piezoelectrics can adapt to the environment and be 'intelligent'.

**How?**

We have mentioned the challenge of wishing to stay close to a phase transition while keeping temperature stability. Therefore, the strategy of my group, since its foundation 13 years ago, has been to look for phase transitions that are driven by parameters that we can tune during the materials synthesis but that can be maintained stable later on, during the life-time of the device. Examples of those control parameters are the chemical composition, whose modification leads to changes in the lattice parameters and, thus internal pressure; or the epitaxial strain, which refers to the modification of the crystal structure (unit cell deformation) of a material by growing it atomic-layer-by-atomic-layer on top of a crystal with similar structure but different lattice size or symmetry. By investigating the phase space of materials as a function of those parameters, it is possible to find phase boundaries for particular compositions or/and strain (measured by the relative difference in lattice parameters between the materials that form the film and the substrate) that are mostly temperature-

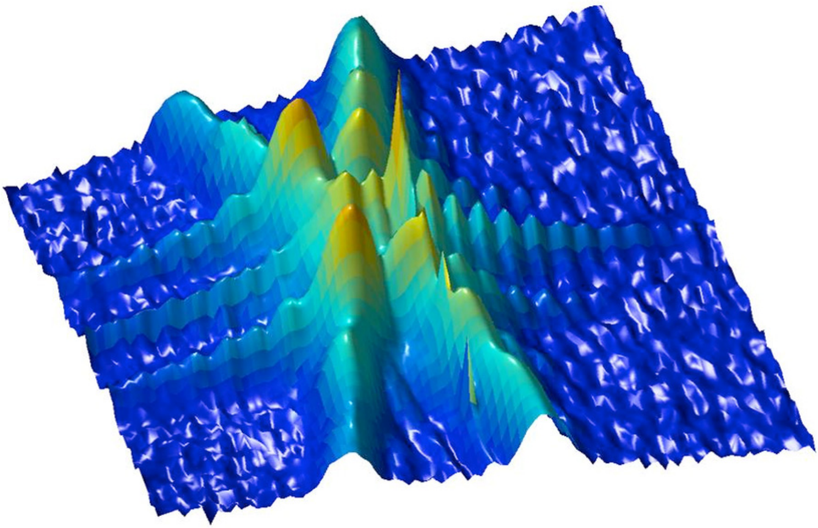


*Figure 1: 3D representation of the reciprocal space map obtained by synchrotron x-ray diffraction around the 001 Bragg peak of a 30nm thick ferroelectric PbTiO3 thin film. The small oscillations (left to right) arise from the film thickness, the large oscillations (top to bottom) arise from the long range periodicity created by the ferroelastic domains upon strain relaxation. Data were taken at DESY (Hamburg).*

independent.
Epitaxial strain can only be successful if it is applied to crystals that are ultra-thin (from a few nanometers to a couple of tens of nanometers). This is in line with the miniaturization and efficient integration goals of modern microelectronics and that is why strain engineering is a strategy followed in labs all over the world, despite the many challenges that it brings about, such as the need to create atomically perfect materials to avoid the relatively large influence of atomic defect, the needs to deal with electrical leakage at thicknesses not too far from those at which electronic tunneling starts to prevail, and the need to deeply understand interfaces and the additional phenomena associated to the symmetry breaking happening at interfaces, electronic reconstruction induced by so-called "polar catastrophes" at interfaces, ion diffusion or the formation of electrical double layers. This understanding is needed in order to build the right devices, which next to the active layer above mentioned need at least (in the simples scenario) a bottom an a top electrode layer, which should also be atomically controlled and, at the same time, should offer the right electronic band structure (ohmic or rectifying electrical contact depending on the application).

**Experiments**

In the course of the years, in the basement of building 18 (Nijenborgh 4), we have built the necessary labs, which now are at the level of the best in the world in this field. A fantastic team is responsible for keeping all up and running (under the technical leadership of Jacob Baas and Henk Bonder); every PhD and post-doc have contributed to get where we are now. Essential is the pulsed laser deposition lab (PLD) to grow thin films with atomic control. A high energy (400 mJ) pulsed laser with 25 nanosecond pulses of ultraviolet light is focused on a pellet of a material with the right stoichiometry that is wished for the thin film. Due to the high energy, material is ablated from the target and ionized, forming a plasma. If a crystal is placed in the same vacuum chamber, the plasma will condense on the crystal, which is at a enough high temperature to promote ion diffusion. The ions of the target will diffuse to follow the energy potential created by the atoms of the substrate crystal and will form a crystal lattice that follows that of the substrate material rather than that of its own lattice. Therefore, the material is deformed (strained) into a structure different from its ground state. In other words, we can create structures that cannot be achieved by normal chemical means. The growth of every single layer of atoms can be followed in-situ

*Our group is increasingly committed to address urgent problems such as materials sustainability and energy consumption.*

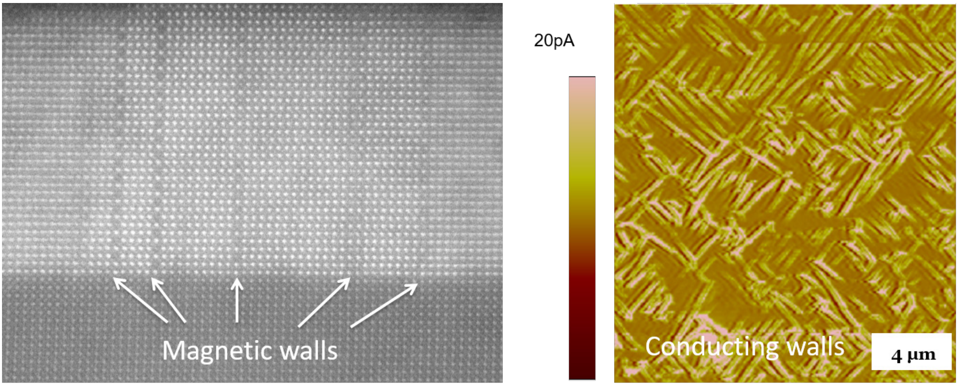



*Figure 2: (left) Transmission electron microscopy image of domain walls separating ferroelastic domains in an antiferromagnetic TbMnO3 film grown on a SrTiO3 crystal. The domain walls become ferromagnetic (from Farokhipoor et al. Nature (2014)). (Right) Conducting probe microscopy image of the conducting domain walls in a ferroelectric BiFeO3 film (from Farokhipoor et al. Phys. Rev. Lett. (2011)).*

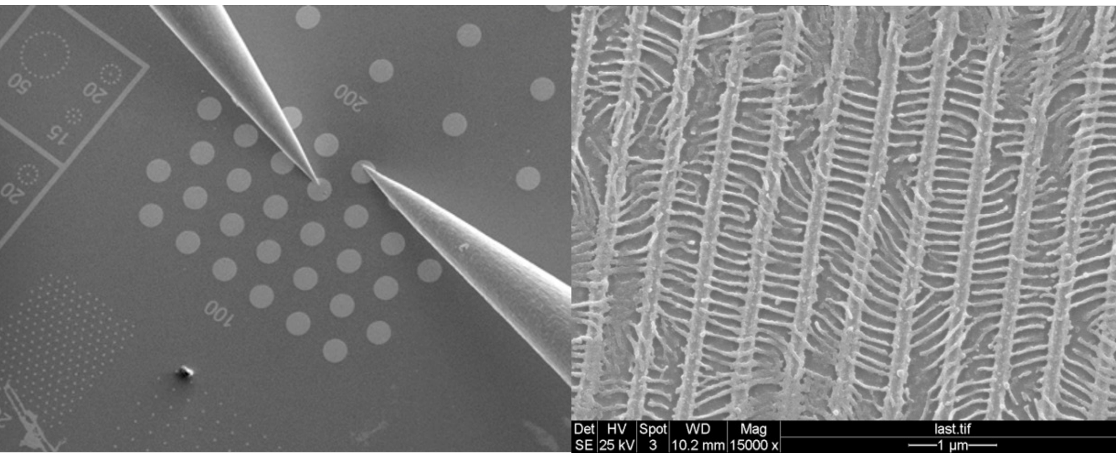
by using electron reflection. By reflecting electrons on the growing surface and following the reflected intensity on a CCD camera, we can see when one full atomic layer has been formed (maximum intensity). In this way we can count the number of atomic layers in our films and stop the growth exactly where we want. This also allows creating artificial materials consisting of multilayers or superstructures made of different compounds. For the growth of oxides, PLD is preferred to other physical vapor deposition techniques, because adding a large oxygen pressure in the growth chamber is possible and it facilitates the proper oxygenation of the material. In addition, the high energy of the species of the plasma, can give rise to phases further from equilibrium compared to other techniques. Other thin film growth techniques that we use in our group are Atomic Layer Deposition and Spin Coating, whose advantage is their industrial scalability.

For the characterization of the films we use a large variety of techniques are needed and many are available in the lab (atomic force microscopy, x-ray diffraction, ferroelectric polarization measurements, magnetization measurements, transport measurements, piezo-force microscopy and interferometry); others are available in the institute or abroad (lithography or transmission electron microscopy, synchrotron scattering experiments). Our most recent acquisition has been a Scanning Electron Microscope inside which we can make electrical measurements while imaging. We are lucky to count with the expertise of Vasek Ocelík on electron diffraction and the help of our colleagues in Bart Kooi's group. Our group members are responsible for the whole process chain, from the growth to the sample characterization and the device performance and, thus, need to master a large number of those techniques, which makes them highly prepared and attractive both for research companies and for academic institutions. We also collaborate with other groups all over the world, which is also a part of the learning experience.

### Scientific Highlights

When the strained films are grown thicker than a few nanometers or a few tens of nanometers (depending on the overall strain) and the elastic energy accumulated (which increases proportional to the thickness) is too large, the films will relax to their ground states. The relaxation mechanism

*Figure 3: In collaboration with Jin Xu (Prof. Loos' group), we have developed networks of ferromagnetic CoFe2O4 self-assembled using block-copolymer templating (right). (Left) View of a sample with electrodes and electrical probes to measure electrical properties while imaging in the Scanning Electron Microscope.*



that is preferred in the case of low symmetry materials (such as ferroelectric and multiferroics) is ferroelastic domain formation (formation of regions with differently-oriented polarization, magnetization and strain). By this mechanism, the film divides into highly periodic and (nanometric) small domains.

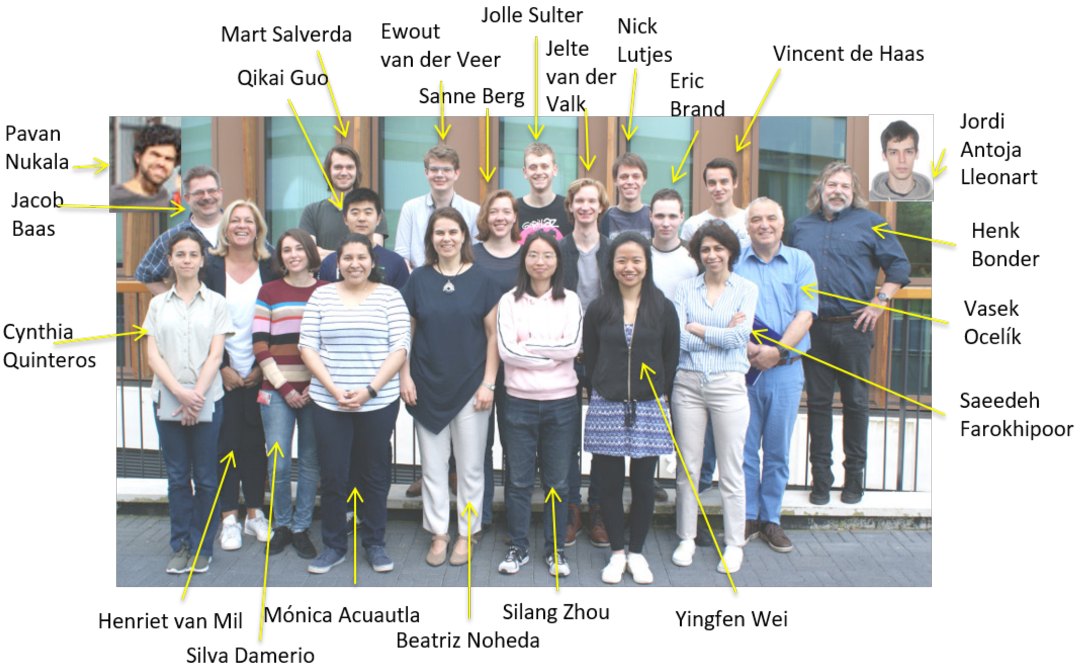
Our group has contributed substantially to the understanding of domain formation and has been instrumental on bringing the community together to investigate at the specific properties of domain walls (very thin, sometimes atomically thin, 2D interfaces, separating different domains). Our group proposed the mechanism for domain wall conductivity that is currently most commonly accepted (Farokhipoor & Noheda, Phys. Rev. Lett. 2011) and has revealed the effects of so-called flexoelectricity (electrical polarization induced by strain gradients) in ferroelectric nanodomains (Catalan et al., Nature Materials 2011). Using a unique combination of symmetry-based materials design, atomically-control materials synthesis, high-resolution structural characterization, atomic probe techniques and transport measurements, we have revealed that novel 2D magnetic phases can be created at domain walls (Farokhipoor, Nature 2014), have reported a novel mechanism for pure in-plane ferroelastic switching (Matzen et al. Nature Comms. 2014) and have discovered a new ferroelectric phase in ultra-thin films of technological relevant Hafnia (Yingfen Wei et al. under review in Nature Materials 2018).

**Intelligent future**

Our group is increasingly committed to address urgent problems such as materials sustainability and energy consumption. The EU has banned the use of toxic lead in all applications, except for microelectronics. The reason is that the best piezoelectrics in the market (so called PZT) contain a lead and the piezoelectrics community has not been able to find an alternative. The PhD projects of Silang Zhou and Jordi Antoja Lleonart are about creating highly responsive piezoelectrics using quartz-based ($SiO_2$-based) piezoelectrics and post-doc Monica Acuautla, who is a mechatronics engineer, is designing piezoelectric devices that can harvest energy from the environment. Together with the municipality of Zuidhorn, Monica will be using their Transferium as a Living Lab to test her piezo-harvesters. This project is a collaboration with the ENTEG institute, where Monica will be soon moving as Assistant professor. Another project together with ENTEG and SRON consists in using piezos on satalites to correct aberration in mirrors. On the memory application side, Yingfen Wei's PhD project and Pavan Nukala's Marie Curie post-doctoral Fellowship are dedicated to exploit the recently discovered ferroelectricity in nanoscale $HfO_2$, going again towards materials that are far more sustainable (abundant, cheap and harmless) that current solutions.

In addition, we have started a research initiative towards adaptable electronic phases spanning a wider range of materials. Variable resistance electronic elements (memristive devices) are required to built adaptable electronic circuits that can allow parallel processing of information, plasticity and co-localization of memory and processing units, the three key characteristics of so-called of neuromorphic (or more gene-

*Figure 4: Group picture in Spring 2018. A pity that Pavan joined a couple of weeks after, that Jordi was abroad making quartz and that I am so bad with Photoshop...I am proud of all of them including our bachelor students of this year; Jolle, Nick, Eric and Vincent.*



rally, cognitive) computing, which holds the promise to lower the power consumption compared to current von-Neumann computers by several orders of magnitude! This is part of a large effort that we start this year in the University of Groningen, the Congitive Systems and Materials Center (CogniGron), that involves researchers from the Zernike Institute as well as from the Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence.

In this context, VENI awardee Saeedeh Farokhipoor is researching how to ultilize domains as nanocapacitors. In collaboration with IBM-Zurich, we have initiated work on the memristive behaviour of ferroelastic domain wall networks in order to investigate their self-learning capabilities. This is part of the PhD work of Mart Salverda and Qikai Guo, both working on different types of materials, and we now also count with the knowledge and help of post-doc Cynthia Quinteros, who is an expert in resistive switching devices. We also take benefit from our environment as top materials institute and, Sanne Berg, after a successful master project, will soon start a PhD in collaboration with our colleagues in polymer physics and chemistry (Giuseppe Portale and Katja Loos) in which she will create self-assembled networks of memristive oxides. Last, but not least, for her PhD project, Silvia Damerio investigates adaptable electronic phases based on thin films that present ordering phenomena and modulated phases (Adv. Electr. Mater. 2016) that can be controlled and manipulated under electric fields. Thus, smart materials for adaptable devices in cognitive architectures with sustainable and low power electronics; all in all, an intelligent future.

# Where are they?

By Jasper Pluijmers

**In the Francken** room, students often seem to think that all the intelligence of Groningen is contained within the doors of the Nijenborgh. While this might or might not be true, a more interesting question is if the intelligence of the universe is contained on Earth. For centuries, mankind has thought about extraterrestrial life, with sources dating back to the second century when the Syrian Lucian of Samosata thought about battling civilizations on the moon. Last century, this science fiction has become science with the massive improvements in detection techniques.

In 1961 dr. Frank Drake came up with the famous Drake equation to stimulate scientific conversation about alien intelligence:

$$N = R_* \cdot f_\mathrm{p} \cdot n_\mathrm{e} \cdot f_\mathrm{l} \cdot f_\mathrm{i} \cdot f_\mathrm{c} \cdot L$$

with the variables

| | |
|---|---|
| $R_*$ | the average rate of star formation in our galaxy |
| $f_\mathrm{p}$ | the fraction of those stars that have planets |
| $n_\mathrm{e}$ | the average number of planets that can potentially support life per star that has planets |
| $f_\mathrm{l}$ | the fraction of planets that could support life that actually develop life at some point |
| $f_\mathrm{i}$ | the fraction of planets with life that actually go on to develop intelligent life (civilizations) |

$f_c$ the fraction of civilizations that develop a technology that releases detectable signs of their existence into space

$L$ the length of time for which such civilizations release detectable signals into space

This equation gives a crude approximation of the amount of alien civilizations in the Milky Way that could be able to communicate with us. With the approximations of that time, the equation would give between $10^3$ and $10^9$ civilizations just in our galaxy. Of course this is a huge spread, but the point of the equation is not to give a very accurate result, it is merely to show that there is very much a nonzero possibility to encounter another civilization.

The question is then: why have we not seen any yet? If there are hunderds of billions of stars in our galaxy with even more galaxies in the universe that could all harbour habitable planets, there should exist a considerable amount of alien civilizations. Even with speeds that are very low compared to galactic scales, considering that the universe has existed for more than thirteen billion years, they should have gotten around by now. This is the idea behind the Fermi paradox and some solutions have been thrown around over the years. If we are actually alone, one could come to some pretty unsettling conclusions. We could be very rare, altough I find it hard to believe, the creation of life might be so rare that the sheer amount of stars in the universe is not enough to counteract this. Another explanation could be that we are the first. After more than thirteen billion years we could be the frontrunner of civilizations. Both of these are more comforting than the third: every civilization destroys itself before it gets to the age of space travel. This is called the great filter and looking back at how humankind has the tendency to eradicate itself is not that farfetched.

But let's assume there are some alien civilizations out there and they are capable of finding and traveling to us, do we actually want that? If they do, then they are without question miles ahead of us in terms of technology. The last time humans found a big continent with other humans they all got slaughtered or killed by diseases. The late Stephen Hawking warned that if we ever get contacted we should be wary of answering back. Maybe we are lucky and the aliens do not harm us, they could use us as study objects or entertainment in the form of some kind of alien zoo. In any case the search for extraterrestrial instelligence, also called SETI, is growing stronger and stronger. Mostly looking at radio signals, the long wavelength makes it perfect for long distance communication, several projects hope to find artificial signs from all over the universe. An example of this is the wow! signal, which was found when scientists were lookin around the 21 cm line, the frequency of a photon emitted by the spin-flip of a hydrogen atom. Because this is so abundant in the universe it would make sense to assume other civilizations are already looking at this frequency and try and send information close to it. In 1977 they found a very strong signal, the wow! signal, but unfortunately no other signals like that have been found in the same spot and it has never been explained.

> *This year, NASA found organic molecules on Mars which could be traces of life.*

Another place to look for life is via spectra of exoplanets. Using the background light of their host stars it is possible to look for absorption lines of organic molecules in their atmospheres. So far not much has been found but the amount of known exoplanets is increasing every year so our chances of finding something become higher and higher.

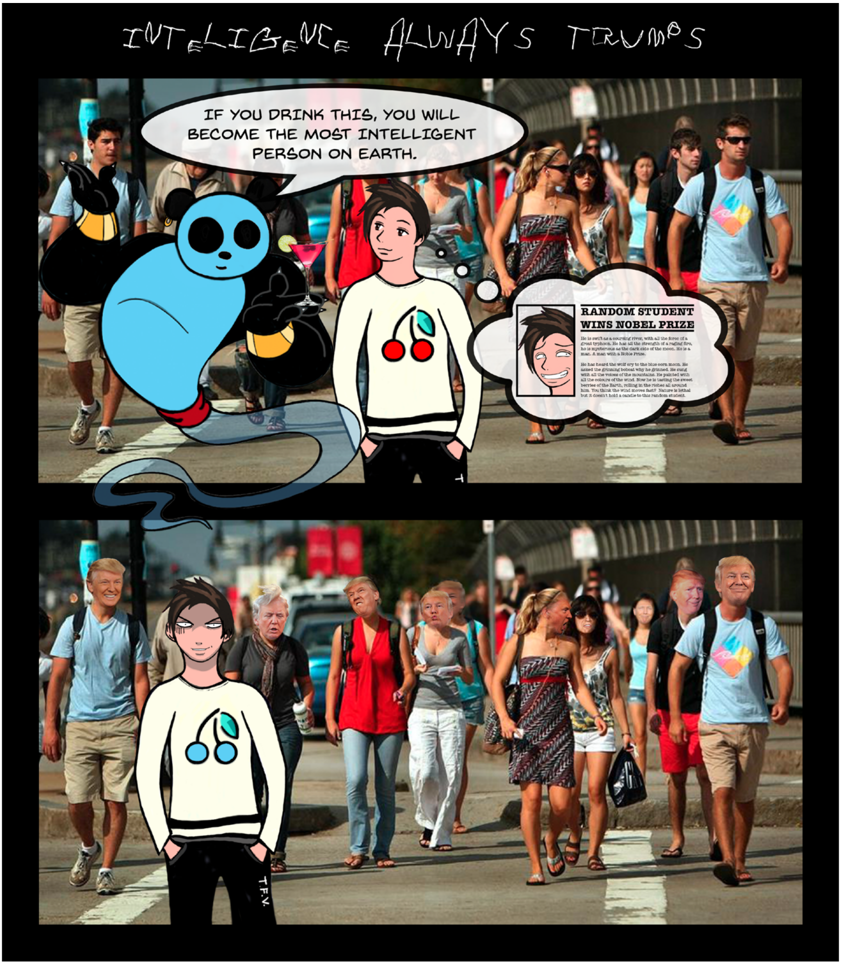
Meanwhile we are also trying to get messages out to others. In 1974 a radio message was emitted by Frank Drake and Carl Sagan which contained some basic knowledge about Earth and humans. It has been traveling quite a while now but was aimed at a cluster 25000ly from us, so we will have to wait for a while to get an answer. Besides this, physical data has also been sent into space in the form of golden disks. Both on the pioneer spacecrafts and the voyager spacecrafts such golden disks were places with information about humans, the position of our solar system using a map of pulsars and some basic physics knowledge needed to decode the disks. While I believe the idea is nice, the voyagers are currently still within a light day away from Earth and thus will not be reaching anyone soon.(see https://voyager.jpl.nasa.gov/mission/status/ for live information about voyager 1 and 2!)

A common theme in all of these examples is that there are no results, therefore it might be useful to first look closer at Earth. While not expecting any intelligence, the possibility of life within our solar system has not been ruled out. On the contrary, more and more signs of traces of life are found. This year, NASA found organic molecules on Mars which could be traces of life, in the present or in the past. Apart from this, several moons such as Europe and Titan have been mentioned as potential life bearing candidates, but no missions have explicitly searched for it on them.

It does not seem likely that we find intelligent life within our lifetime, but to me it seems sad if we never find any form of it. Even if contacting any is not a good idea, it would be comforting to know that we are not alone in this enormous universe.

# Comic

By Kathinka Frieswijk



# Puzzle

By Steven Groen

**When one thinks** of intelligence, one might think of the AIVD, the Dutch intelligence service. Francken members associate the AIVD with the Christmas puzzle we try to solve every year. The most recent edition of this puzzle featured a question dedicated to Raymond Merill Smullyan (1919-2017), an American mathematician, magician, concert pianist, logician, Taoist, and philosopher. Since some members found this question somewhat disappointing (and since the AIVD refused to write a rubric for us), I decided to make such a puzzle too, to do right by Smullyan. As this will be the last puzzle I make as a member of the editorial board of the Francken Vrij, I let myself go a bit and made a longer puzzle than usual.

### Introduction

This puzzle concerns the saga of an intelligent freshman named Raymond. Raymond's purpose is to obtain a Francken almanac. Unfortunately, it is not trivial for Raymond to obtain this almanac. He must use his intelligence repeatedly to find it.

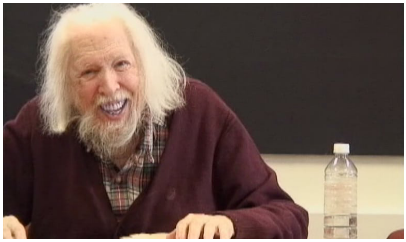
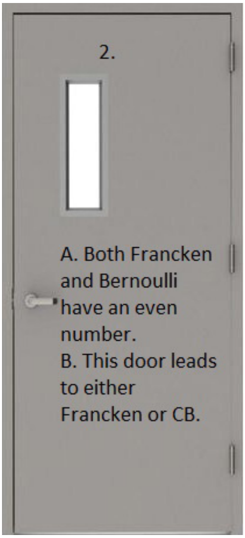


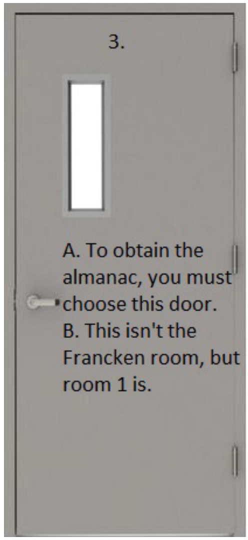
*Figure 1: freshman Raymond.*

### The doors

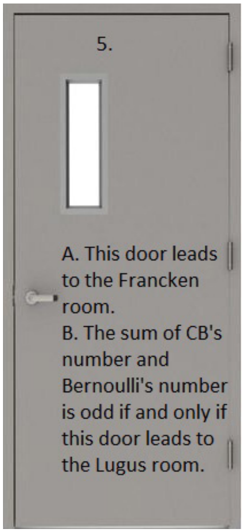
Raymond examines the Nijenborgh and concludes that five study associations reside in this building: Bernoulli, CB, FMF, Francken and Lugus. If he opens the wrong door, he will become an active member there and never obtain the right almanac, so he must infer which room is the Francken room beforehand. It is given that the Francken door only contains true statements and all other doors contain only false statements. This five door problem is visualized, poorly, on the forthcoming page. Raymond determines which door leads to the Francken room. Can you do this too?


1.
A. This is not the FMF room.
B. I want you to get me a beer.


2.
A. Both Francken and Bernoulli have an even number.
B. This door leads to either Francken or CB.


3.
A. To obtain the almanac, you must choose this door.
B. This isn't the Francken room, but room 1 is.


4.
A. This door does not lead to the CB.
B. I want you to get me a beer.


5.
A. This door leads to the Francken room.
B. The sum of CB's number and Bernoulli's number is odd if and only if this door leads to the Lugus room.

## The board

Raymond manages to enter the right room: the Francken room. In that room, he encounters the entire board: Joris, Chantal, Bradley, Jeanne and Leon. Precisely one of these board members has an almanac. There are two types of board members: technicians and theorists. Technicians always speak the truth, whereas theorists always lie. Raymond means to find out which board member has an almanac and of which type this board member is. Since this entire situation is purely fictional (we started out with an intelligent freshman), the factual field of study of board members is irrelevant. Raymond engages in a conversation with the board members.

Raymond: "Leon, is there an even number of theorists?"
Leon: "Yes."

Raymond: "Jeanne, is the person with the almanac a technician?"
Jeanne: "Yes."

Raymond: "Bradley, are you a theorist without an almanac?"
Bradley: "No."

Raymond: "Chantal, are there more theorists than technicians?"
Chantal: "Yes."

Raymond: "Joris, is Bradley a technician?"
Joris: "Yes."

Raymond infers the type of a board member. He asks this board member some more questions to find out which board member has the almanac, That board member shows Raymond three vaults in the board room, one of which contains an almanac.

## The vaults

In the mean time, all board members drink an exorbitant number of *leermomenten* of *graanjenever*. This causes them to forget the words 'yes' and 'no'. Instead, they use 'Yusuf' and 'Ali', but Raymond doesn't know which of these means 'yes' and which means 'no'. He asks some questions.

"Is the almanac in vault 1?" - "Yusuf."

"Is the almanac in vault 3?" - "Ali."

"What was the correct answer to the question I asked you in the members room?" - "Ali."

## The code

The vault asks for a code consisting of three numbers: the number of the Francken door, the number of letters in the name of the board member whose type was first identified and the number of the correct vault. Raymond enters this code, which is a prime number, and reads the almanac. What code did Raymond enter? Send this code to the editorial board and you can win an almanac.

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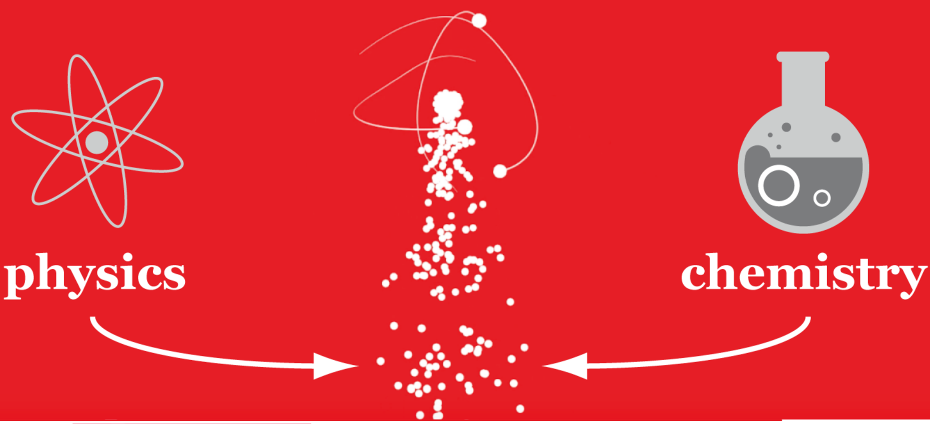


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Our activities cover both Bachelor and Master levels in the field of Physics and Chemistry. But, since it is our mission to train a new generation of researchers in cross-disciplinary approaches to research and equip them with the diverse skills required by modern science, we also have programs breaking the traditional boundaries between disciplines. We are very proud on our interdisciplinary Top Master program Nanoscience in this regard, which was rated the best Master program of the Netherlands the last four years in a row by national study guides. Next to this, we also offer the High Tech Systems and Materials Honours Master, which tackles real-life product development challenges in the same interdisciplinary fashion.

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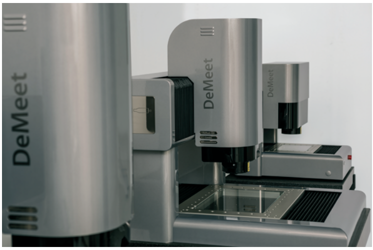


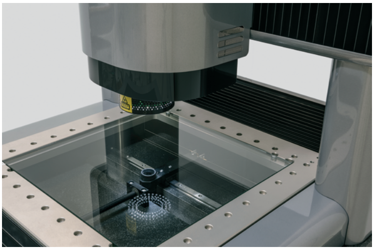

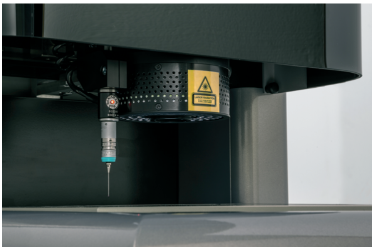

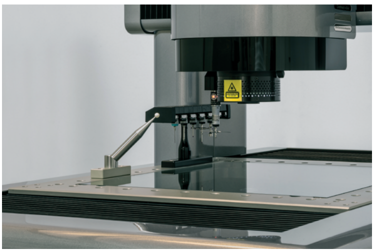

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Aangezien we onze activiteiten uitbreiden, zijn we continu op zoek naar enthousiaste medewerkers om ons team te versterken. Als jij wilt werken in een bedrijf dat mensen met ideeën en initiatief waardeert, dan is Schut Geometrische Meettechniek de plaats. De bedrijfsstructuur is overzichtelijk en de sfeer is informeel met een “no nonsense” karakter.

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