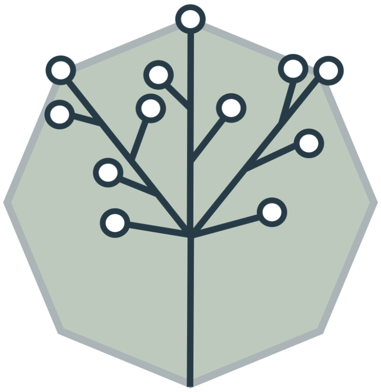
CERN Ideasquare Progress Report
Team 3

Alysha Blömker, Bartłomiej Grochowski, Nassim Beladel, Yiyuan Chen



TU Delft & University of Amsterdam
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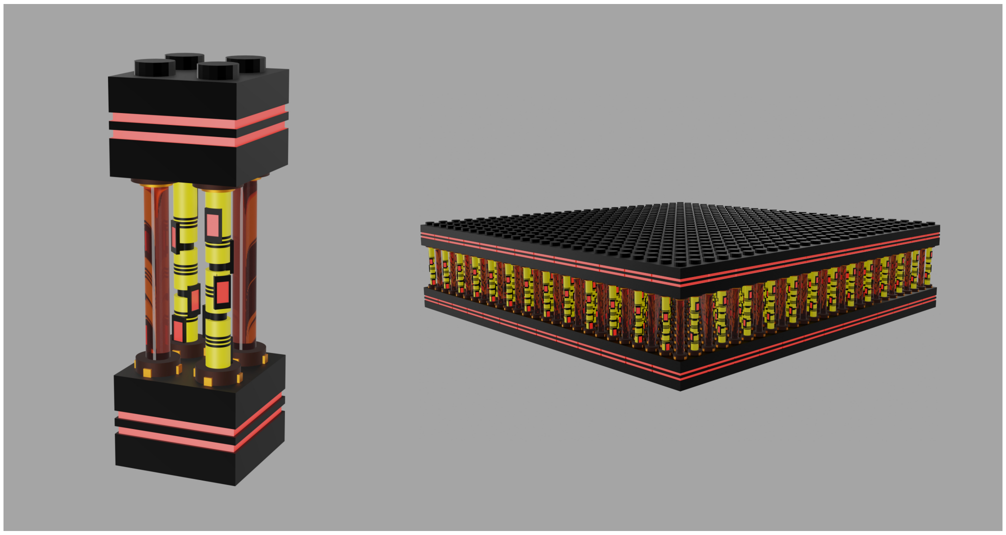


3D model of team's final prototype

Contents

1 Introduction

Team 3 consists of four students from TU Delft and the University of Amsterdam: Alysha Blömker, Bartłomiej Grochowski, Nassim Beladel, Yiyuan Chen. Each member brings a distinct background to the table. The technology assigned to this team is the AHEAD technology developed at CERN. This progress report records their journey through the innovation process and their collaborative engagement with this technology.

2 Team composition and members' background

2.1 Team members' background

Nassim Beladel

Age: 20
Studying: BSc Electrical Engineering
University: Delft University of Technology
Role: Diplomat

I am an incoming third-year BSc Electrical Engineering student at TU Delft, and I have participated in the CERN IdeaSquare Summer School to fulfil the 'interfaculty component' of my Honours' Programme. The Summer School quickly piqued my interest, as I enjoy treading at the forefront of science, technology, and innovation, and its collaboration with the prestigious CERN – with the prospect of working on-site during the programme – certainly did not diminish my predilection. My primary academic interests lie in embedded computing and hardware applications, neuromorphic engineering, as well as distributed and/or autonomous (sensing) systems. To pursue these interests, I will attend ETH Zürich for my minor abroad in the first semester of academic year 2023/2024. Beyond these interests, I like to remain politically and socially engaged, as expressed by my past involvement with, e.g., the national Dutch UNESCO Youth Committee, or the Faculty Student Council. Similarly, I have recently founded JARA, the Youth Advisory Council of the municipality of Alphen aan den Rijn, to promulgate youth political involvement. Altogether, I hope to combine my political, social, and academic activities to realise my overarching ambitions and ideals.

Yiyuan Chen

Age: 21
Studying: BSc Mathematics and Physics
University: University of Amsterdam
Role: Expert

I am a double bachelor student in Mathematics and Physics entering my third year at the University of Amsterdam (UvA). I have chosen the CERN Ideasquare Summer School as part of my Physics Honours programme. During the course of my study, I developed a strong interest in quantum computing and topology, and gained research experiences in particle physics and condensed matter physics. Outside of my studies, I find joy in playing the piano and have achieved notable placements in several competitions such as the Steinway Concours, the Princess Christina Concours and the Young Pianist Foundation Competition. Combining this hobby with my academics, I collaborated with fellow UvA students on an outreach project, teaming up with composer Petra Cini from the Royal Conservatory of the Hague to present abstract mathematical concepts like Group Theory and Lie-Groups to a broader audience. While my UvA studies focused primarily on theory, my interest in hands-on practicality in my Honours Programme drove me to pursue experiences like the CERN summer school.

Alysha Blömker

Age: 20
Studying: BSc Nanobiology
University: Delft University of Technology
Role: Chair Person

I'm going into my third year of the Nanobiology Bachelor at the TU Delft. Through participating in the honours program, I got the opportunity to participate in the CERN IdeaSquare Summer Course. I was drawn to this course because of its emphasis on interdisciplinary team work and societal impact. Due to the inherently interdisciplinary nature of my study (it is a mix of physics, mathematics and biology) I have an affinity for crossing the boundaries between field. Yet within my study there were few opportunities to collaborate with students from other courses, so this summer course was ideal. I also think it is important to not loose sight of the societal impact of science whilst in an academic environment. Over the course of my bachelor I realised how much I enjoy learning about physics (and applying it to problems!). That is why I will pursue a physics bridging minor in the coming academic year. In my free time I enjoy going hiking, often in the dunes - they are one of the few places with altitude changes here in the Netherlands!

Bartłomiej Grochowski

Age: 20
Studying: BSc Aerospace Engineering
University: Delft University of Technology
Role: Innovator

I am a Polish student, soon-to-be third-year BSc Aerospace Engineering student at TU Delft. After my first year of studying in the Netherlands, which was a difficult time because of lockdown, I have decided to have my future in my hands and to work hard for success. That is why when I first got to know about the CERN IdeaSquare Summer School, I felt a strong feeling of ”I have to do this!”, especially as it would fulfill the requirements of my Honours Programme. ”Innovation”, ”scientific paper”, ”industry experts” - these words stuck in my head for a long time. My background is strongly related to engineering, but it is not limited to aerospace - I took part in some projects concerning Computer Science, Electrical or Mechanical Engineering before. Currently, I am participating in mainly projects in my degree field, like my Honours ATC AI interface project, Lambach Aircraft or Da Vinci Satellite, but also I am excited to work on other less-related things, like this summer school or my strongly robotics-related minor abroad at Korea Advanced Institute of Science and Technology. I hope that my fascination about aerospace, together with passion towards STEAM will lead to a great success of projects like this!

"Together, we are Team Arbores!"
(Team video: `https://youtu.be/avjQKklQ9LY`)

2.2 Rules for the good functioning of the team

In order to have a smooth collaboration within the team, the team members agreed at their first meeting to establish a set of rules for the team. After discussing each other's strong suits and weaknesses, the team developed the following set of rules to target their strong suits and weaknesses:

1. Address problems when they arise - don't wait!
2. Be open to feedback, be understanding.
3. Ask help when you need it.

3 Innovation Process, Choices and Milestones

This section introduces the innovation process and its steps, and describes them in detail. It will show how the team came up with many ideas, and present the choices it made. Additionally, it will showcase the major breakthroughs that led to the final design.

3.1 Setting up the process

After being assigned the AHEAD technology to work on, the team's objective was to come up with an innovative and groundbreaking application of it. Thus, it was crucial to set up a apporpiate innovation process, which was selected to be the Design Thinking framework. The first step was to understand the AHEAD technology and open the team members' minds for possible ideas. This was done during the Define phase, during lectures and meetings conducted in May and June in Delft. The major outcomes of this phase were: "We know how to" statement, establishing what is unique about this technology and what have we learned about it, and a list of 100 possible sectors that could make use of this technology.

With proper understanding of the material to work on, the next step was to narrow down the list, and with selected 25 sectors develop the opportunity fields. This was done during the 3-day Design Sprint in July in Delft. Additionally, the team assessed the impact of these opportunity fields, together with other metrics like feasibility, cost, expand-ability or compliance with the Sustainable Development Goals. Finally, some low-fidelity prototypes of the 3 most favourable applications were made to verify some assumptions made in the process.

The final stage of the ideation process took place in Geneva at CERN IdeaSquare, during the second week-long Design Sprint. There, the first step was to go back and look at 8 possible applications, and properly analyse them again. With again narrowing the possibilties to 3 applications, factors like customer journey, touch points and values of it were analysed. The most important part of this sprint (in case of our team) was to contact industry experts and to listen to their vision and needs. With this valuable feedback, the team established the unique value propositions and gradually developed the 3 ideas, to finally select one and create higher-fidelity prototypes and a presentation of the final design.

The ideation process can be visually described by Figure 1. In the figure, the steps are written in the order that the team followed. The curved lines represent the going forwards and backwards with the considered applications - gradual expanding and narrowing the working space.

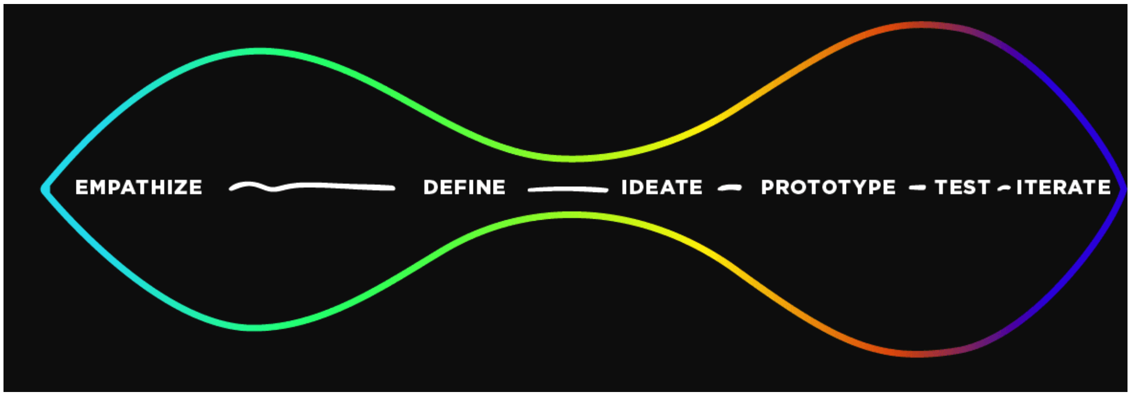


Figure 1: Ideation Process Visualization.

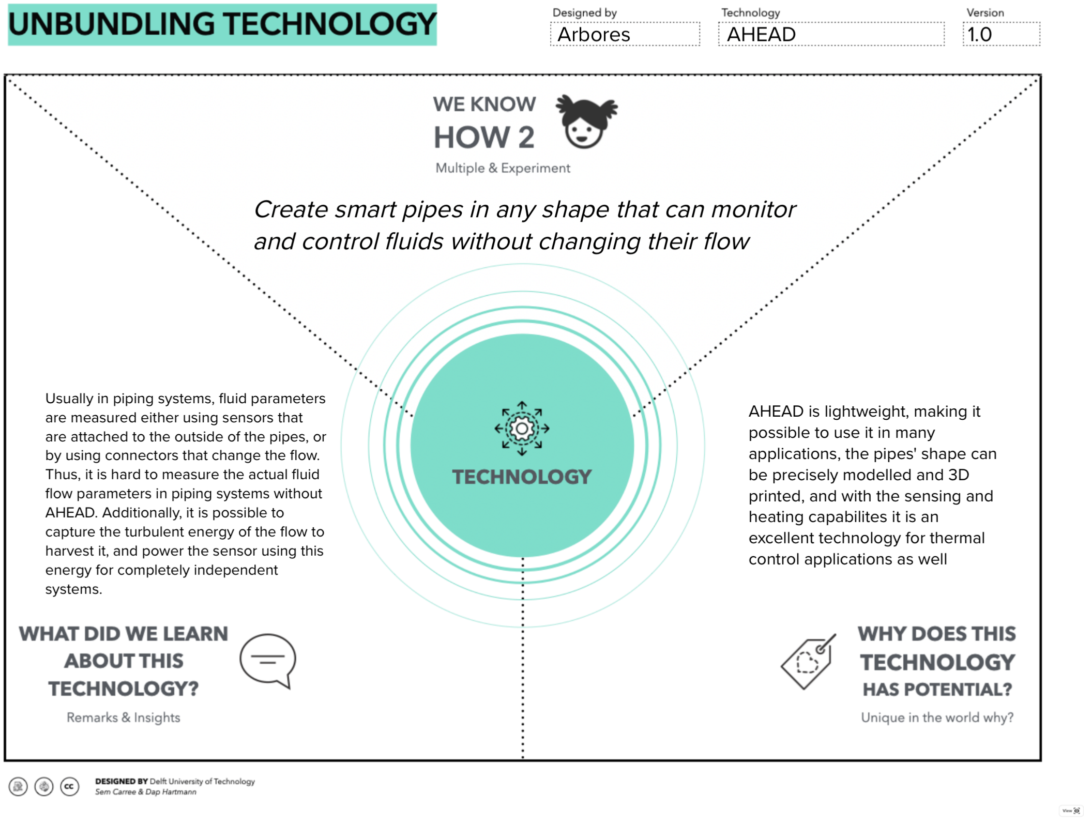
3.2 Technology unbundling

The first step of the set-up ideation process was to properly understand the working material. With the assigned AHEAD technology, the team started the process of researching its capabilities and possibilities.

AHEAD (Advanced Heat Exchange Devices) technology created by the team of scientists at CERN and CSEM is about creating 3D printed metal pipes, which allows them to be created in virtually any shape.

These pipes are equipped with embedded sensors that can monitor the fluid parameters, without obstructing its flow. Additionally, the pipes are equipped with heater elements for precise control of the fluid temperature, and capacitive membranes that can harvest energy from the flow. This allows the sensors to be self-powered, and to wirelessly transmit the sensor data. The research team's motivation behind the project is to use them in temperature control of the advanced sensing equipment present at CERN's Large Hadron Collider stations like CMS. The team also envisioned this system to be applicable in refrigeration, space temperature control systems, agriculture or surgical robotics.

To get the proper view on the AHEAD technology, the team carefully studied the material about the technology available online - research paper, articles, interviews and tech card. An important part of this study was also to have a meeting with a member of the research team, Chrysoula Manoli. She summarized the main concepts behind the technology, and provided feedback on initial ideas for application of this technology. As the purpose of this project was to come up with an original innovative application, any use-cases already envisioned by the research team were discarded for development, but the team decided to have them in mind for reference purposes. The outcome of this phase was the canvas present in Figure 2. It presents the three main concepts that are crucial to understand the technology - a "We know how to..." statement that encaptures the four main capabilities of the AHEAD technology, remarks and insights of the technology, and the uniqueness of its features.



Designed by: Arbores
Technology: AHEAD
Version: 1.0

Create smart pipes in any shape that can monitor and control fluids without changing their flow

Usually in piping systems, fluid parameters are measured either using sensors that are attached to the outside of the pipes, or by using connectors that change the flow. Thus, it is hard to measure the actual fluid flow parameters in piping systems without AHEAD. Additionally, it is possible to capture the turbulent energy of the flow to harvest it, and power the sensor using this energy for completely independent systems.

AHEAD is lightweight, making it possible to use it in many applications, the pipes' shape can be precisely modelled and 3D printed, and with the sensing and heating capabilites it is an excellent technology for thermal control applications as well

DESIGNED BY Delft University of Technology
Sem Carree & Dap Hartmann

Figure 2: "We know how to..." canvas.

Before coming up with the possible industry sectors for application opportunity fields, for further reference and as a catalyst for team's creativity, the team created a tech video that describes and explains the technology in a bit more detail. The video can be acessed here: `https://youtu.be/iZZth6FrPRk?si=1jt9OgwhNSiegBA_`.

For yet one more way to catalyse the design thinking process, a visualization present in Figure 3 of the technology has been made by an external graphics designer, Jelle. This way, the team had a paper representation of the technology, enabling the team's visual minds to work in a more efficient way for the creative process.

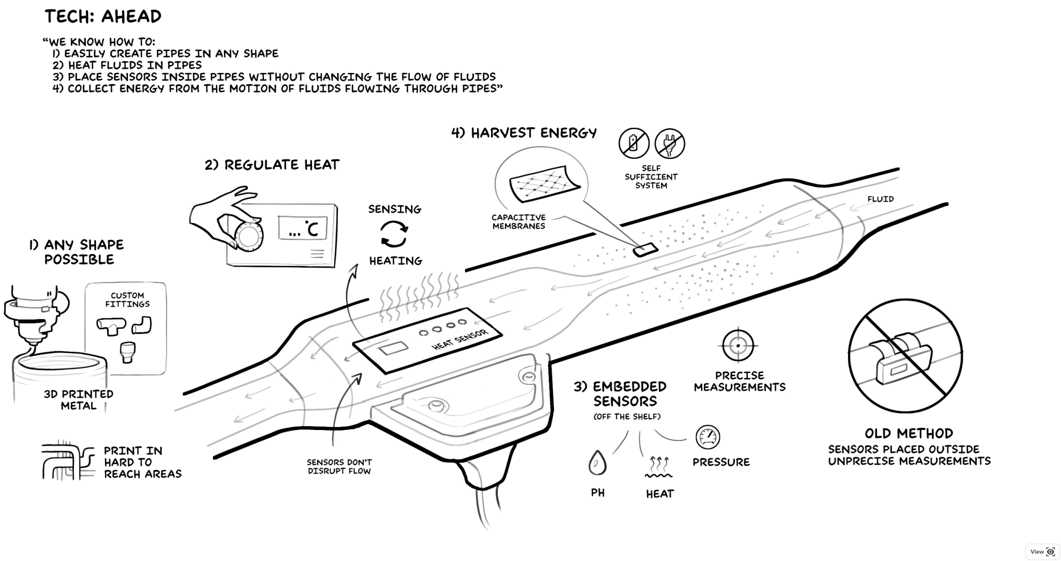


Figure 3: AHEAD technology visualisation made by Jelle.

With this tools in hand, the team had a brainstorming session to come up with the 100 domains and subdomains of industry that could make a good use of the technology. The main purpose of bringing so many possible opportunity fields was to enforce out-of-the-box thinking and escape the so-called "brain cage". The more obvious, but potentially excellent applications came up first, but after approximately 60 sectors it was necessary to dive deeper into the industry and think of some extraordinary usages, even if they sounded ridiculous at first. An example of this would be coffee industry, where the AHEAD technology would be used to monitor the coffee brewing process. The final list of 100 applications can be seen in Appendix A

3.3 Domain exploration

During this phase of the innovation process, which primarily occurs during the 3-day sprint in Delft, the team engages with the wide array of 100 domains (see Appendix A), spanning from Industrial Waste Management to the Quantum Computing Industry. The first objective for these domains was to narrow them down to 25 domains. In order to do this, the team categorized the 100 domains into the following categories:

- Scientific research
- Transportation
- Manufacturing
- Cultural / Public services
- Infrastructure
- Digital.

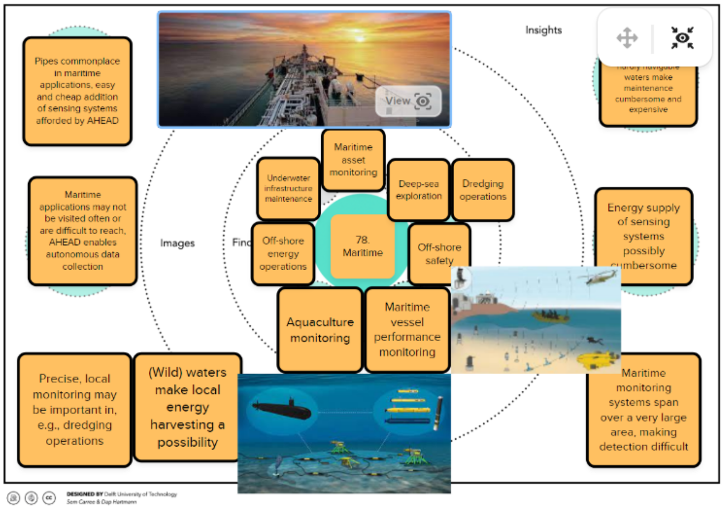
After categorizing the domains, the team proceeded to select domains based on the feasibility and compatibility of the technology with each respective domain. In doing so, the team ensured representation across each category. The 25 domains that emerged from this process are outlined in figure 4.

Scientific/Research	Transportation	Manufacturing	Culture/Public Services	Infrastructure	Digital
1. Environmental Monitoring [29, 30, 31]	5. Automobile Industry [15, 19, 23]	**13. Robotics [12, 59]**	46. Restaurants	22. Water Management Systems [17]	76. Crypto mining
31. Scientific and Technical Instruments	78. Maritime	**41. 3D Printing [6]**	90. Aquariums and zoos	92. Recycling facilities	
2. Oceanography [1, 3, 11]	6. Aviation Industry [21, 27]	67. Biofuel production	58. Biotechnology	10. Data Centers	
		34. Food Processing Indsutry [7, 8]		15. (Energy Generation)	
		17. Electronic Components Industry [35]		4. Oil and Gas Industry[2]	
		29. Pharmaceutical Industry [10]		77. Security/ Anomaly detection	
		30. Laboratory Equipment [41]		25. Waste Processing	
		3. Chemical Industry [9]			

Figure 4: 25 selected domains.

Upon this selection, the team's focus shifts to gaining an in-depth understanding of these domains and the potential role their technology can play within them. This involves a comprehensive research approach conducted over five rounds. During each round, team members choose a domain and delve into it, employing a canvas similar to the one depicted in Figure 5.

After selecting these 25 domains, the team needed to gain an in-depth understanding of these domains and the potential role their technology can play within them. To achieve this, the team went through five rounds of research. During each round, each team member had to pick a domain, and work it out by filling out the canvas as given in figure 5.



78. Maritime

Maritime asset monitoring

Underwater infrastructure maintenance

Deep-sea exploration

Dredging operations

Off-shore energy operations

Off-shore safety

Aquaculture monitoring

Maritime vessel performance monitoring

Pipes commonplace in maritime applications, easy and cheap addition of sensing systems afforded by AHEAD

Maritime applications may not be visited often or are difficult to reach, AHEAD enables autonomous data collection

Precise, local monitoring may be important in, e.g., dredging operations

(Wild) waters make local energy harvesting a possibility

waters make maintenance cumbersome and expensive

Energy supply of sensing systems possibly cumbersome

Maritime monitoring systems span over a very large area, making detection difficult

Figure 5: Example of the canvas.

The domain is placed at the center of the canvas. The first layer outlines potential applications of the technology within the domain, while the second layer incorporates illustrative images. The third layer contains insights gleaned during research. Throughout this process, the team opted not to pursue five out of the 25 domains: Energy Generation, Electronic Components Industry, Data Centers, Recycling Facilities, and Oil and Gas Industry.

The decision to discard Energy Generation and Electronic Components Industry arose from the team's challenge in acquiring sufficient information regarding the technology's applicability in these domains. In the case of Data Centers, although the AHEAD technology displayed an evident application in creating a smart cooling network, the team recognized its limited scope within this context. Consequently, the team shifted focus to domains offering greater versatility. Recycling Facilities and Oil and Gas Industry were disregarded due to personal preferences and ethical considerations of team members. Ultimately, this comprehensive process enhanced the team's grasp of their technology's potential across the remaining 20 domains.

3.4 Domain selection

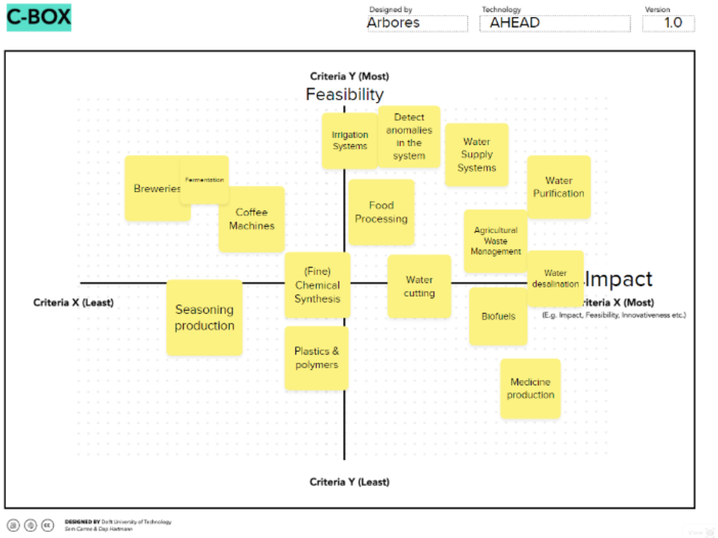


Figure 6: 14 selected domains

Among the 20 domains previously considered, the team proceeded to choose their top 14 preferences, as indicated in figure 6, based on their assessment of feasibility and impact. The subsequent objective was to narrow down this selection to three domains. At this point, the team's primary interest was directed towards water management systems encompassing irrigation, water supply, purification, and desalination, owing to their perceived potential for considerable feasibility and impact compared to other alternatives. After conducting several rounds of research, the team included desalination among their final three choices.

Instead of exclusively focusing on water management systems, the team sought diversity in their choices. An enlightening conversation with Professor Tony Kiss prompted the inclusion of microreactors as one of their final three selections, given their significant promise in both the biological and medical fields. As research progressed, the team's fascination extended to the food production industry. Upon gaining insight into pasteurization processes, the team recognized the applicability of the AHEAD technology in this domain, leading them to include pasteurization among their final choices.

However, a subsequent discussion with Dap Hartman revealed that the AHEAD technology could offer only incremental enhancements to the selected domains. Therefore, the team had to explore domains with the potential for more exponential advancements. Their initial concepts encompassed an ocean sentinel for coastal monitoring, a precision-enhanced smart nozzle for water cutting, and an integrity detection system for pipes. However, after thorough evaluation, these ideas were discarded due to inherent limitations. The ocean sentinel concept faced challenges with fouling and sedimentation, and the smart nozzle and integrity detection system were deemed to offer relatively modest improvements.

In the search for a more fitting domain, the team revisited the microreactor idea following discussions with Tor Henry from Vitroscope. These microreactors, operating at millimeter scales, demand high precision and non-disruptive environmental control—characteristics that align seamlessly with the capabilities of the AHEAD technology. Furthermore, the size compatibility between the AHEAD technology and microreactors accentuates their suitability. With broad applications in the medical field, particularly in mammalian cell cultivation such as stem cells, the team ultimately selected microreactors as their final pursuit. A prototype of this concept was subsequently developed, with details outlined in the following chapters.

4 Clearly Defined Problem

To clearly define the problem addressed by our proposed innovative application of the AHEAD technology, we first need to sketch an overview of the present-day industrial and academic realities of microbioreactors, henceforth referred to as MBRs. Within the field of biochemical technology, namely, one problem in particular prevails: the problem of high-throughput (bio)process development. Traditional applications usually lack in either the high levels of accuracy and control required by complicated cell culture development and sustenance, or otherwise in sustainable scalability, leading to an overall lack in solutions to scaling up this promising field to industrially viable standards. Recent biotechnological advances particularly highlight the shortcomings of existing applications as, e.g., in the case of genetic engineering. An ever increasing number of mutated strains can be produced, generating an ever greater number of concurrent evaluatory bioprocesses that need to be run. However, disregarding even such possibilities introduced by recent advances, altogether novel and perhaps even revolutionary forms of therapy may be enabled by the development of proper, scalable bioreactor technology.

4.1 Stem-cell cultivation

Hence, attempting to innovate beyond traditional boundaries, we started investigating opportunities within the field of *stem-cell cultivation*, to advance towards the realisation of patient-specific cell-based therapies. Stem-cells, namely, possess an unrivaled potency to the end of developing regenerative medicine, massively scaling up drug assay-taking, accelerating patient-specific research, and other such cutting-edge biopharmaceutical applications [1]. A specific example would be illustrated by the case of bone-marrow transplants, as required by, among others, leukemia patients. Enabling the cultivation of patient-specific bone-marrow populations can increase chances of successful transplantation, as the patient's body is less likely to reject the transplanted organ as a harmful foreign entity.

Furthermore, to help illustrate the revolutionary potential of large-scale stem-cell cultivation, we would like to redirect the reader to section 6, where the reader can find a non-exhaustive list of conditions that can possibly be treated by a sustainably scalable and properly developed stem-cull cultivating platform.

4.1.1 Choice for the bioreactor

Why should bioreactors in particular even be considered as a suitable technology for stem-cell cultivation? The answer is quite simple: its design most easily allows for the proper mimicry of real, in-vivo biological conditions within which stem-cell differentiation normally occurs. "Flat biology", i.e., biological analysis and bioprocess development on 2D-topologies such as Petri dishes, cannot recreate the conditions found in the (human) body, boasting unrealistic surface area contact with the culturing medium and being incapable of reproducing three-dimensional stimulation patterns (e.g., nutrient gradients or 3D-morphological development). Bioreactors, on the other hand, can potentially enable the accurate reproduction of these complex in-vivo conditions through precise parameter monitoring and control systems within its three-dimensional interior. Moreover, bioreactors can allow for the continuous monitoring and control of the culture and its medium in a more complicated, three-dimensional fashion that simply cannot be reproduced in a two-dimensional medium, which instead requires batch-wise operation, making it intrinsically uncontrollable [2]. Hence, the bioreactor seems to provide a worthwhile venue to the end of stem-cell cultivation, prompting us to consider the technology as a potential critical enabler in the field.

4.1.2 Problem exposition

Before delineating our suggested solution with the AHEAD technology, it is of use to first explore the problems at hand in greater detail, and analyse the precise shortcomings of existing technologies. First of all, it is important to note that the great barrier between the present and the successful implementation of stem-cell-based therapies on a large scale includes a lack of fundamental understanding regarding the precise cellular and even molecular interactions that critically influence stem-cell differentiation processes [1]. Moreover, to uncover these critical mechanisms, we still need to develop the proper sensing technologies and/or techniques that allow us to monitor highly important cell culture parameters, such as the detection of the number of cells or inference of the differentiation-stage – alongside other technical limitations, such as a lack of proper bioprocess modelling or control strategies. These problems are only further indicative, however, of a distinct absence of a scalable, easily deployable, and economical platform to accelerate the development and verification of the required technologies and strategies. The construction of novel in-vitro, high-throughput bioprocess profiling strategies to systematically evaluate parameter-influence on selective cell fate control necessitates these aforementioned characteristics, to enable the massively parallel investigation of stem-cell niche manipulation and its subsequent results [3]. These findings underline a definite need for accurate, non-disruptive online monitoring of parameters and the development of automated control systems, by means of unveiling the relationships between freely manipulable in-vitro conditions and cell fate determination. Such an incorporation of predictive models into bioreactor technology could, in turn, even further economise bioprocess development by optimising operational control to minimise expensive reagent use and cultivation time. Either way, the development of viable stem-cell therapies necessitates this investigation into the relation between a wide range of varying temporal (e.g., oxygen or pH) profiles and differentiation fate. Only when these relations have been reliably established to be commonly and clearly reproducible can newly emerging bioreactor technologies properly contend with present industrial realities and standards.

4.2 Concluding remarks

As postulated in recent literature on the topic, milliliter-scale MBRs might prove to be the ultimate solution to these quandaries, possessing sufficient volume to culture relatively larger, more complicated populations, yet remaining sufficiently small to allow for very precise monitoring and control and, most saliently, the possibility of massively parallel deployment [4]. This latter possibility in particular, in turn, may enable the exciting field of bioprocess development to finally scale up to industrial standards. Consequently, the intrinsic milliliter-scale of the AHEAD technology encouraged our investigation into possibilities of convergence – as is presented in the following chapter.

5 Solution

We propose a micro-bioreactor with highly accurate parameter monitoring and control that allows for the cultivation of highly sensitive stem cells. The solution is termed a Life-Cell Sustaining Device (LSD).

Re-thinking the applications of the AHEAD pipe technology, we want to create 3D printed micro-bioreactors that have sensors embedded directly into the reactor container. This allows for non-disruptive measurements of local parameters. Further more, we will integrate actuators to form a complete feedback systems that can ensure stable growth parameters for the cells. Through the utilisation of 3D printing, we create a product that is manufactured easily and allows the user to select combinations of sensors and actuators that are specific to their needs.

Our reactor is designed to be used in highly scalable parallel systems. This means that hundreds of our LSD micro-bioreactors can be used at the same time, which exponentially decreases the amount of time needed to grow cells amongst different conditions.

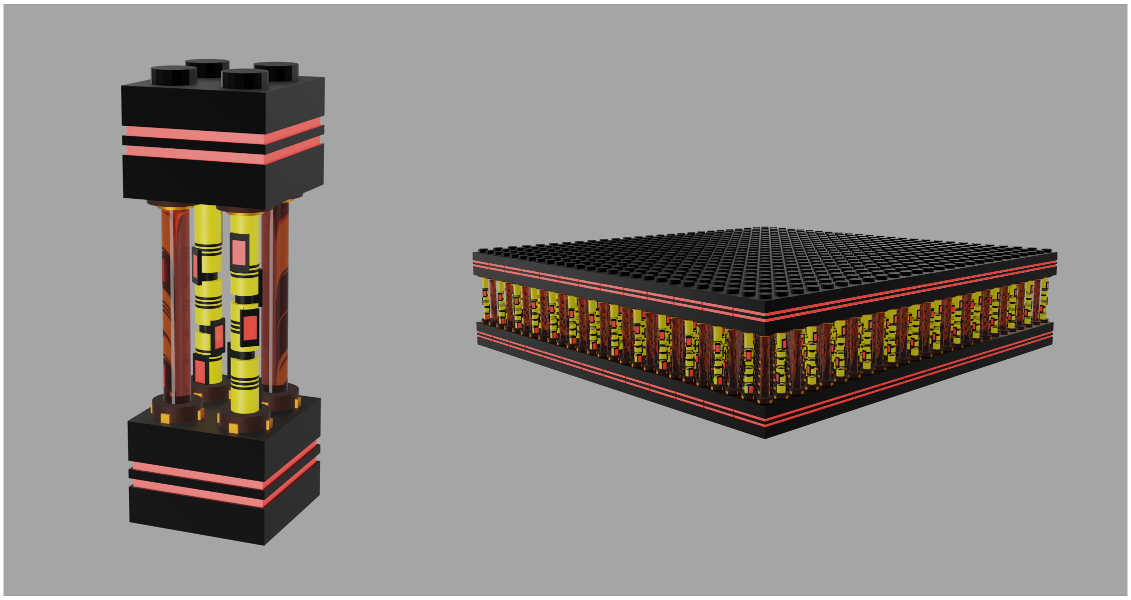


Figure 7: 3D renderings of the LSD micro-bioreactor as one unit (left) and in parallel system (right)

Compared to existing micro-bioreactors, the LSD micro-bioreactor will be cheaper and more automated. By developing intelligent feedback systems, we not only spare the user labour costs, but because the reactor is self-contained it does not require a highly specialised laboratory environment. Because of this the LSD reactor be deployed in lower economically developed countries. Through this we hope to reduce the global health inequality.

6 Impact and market exploration

Our application has immense potential for impact, both on a societal and entrepreneurial realms.

Through facilitating the cultivation of stem cells, the LSD Micro-Bioreactor can innovate in one of the most impact full sectors: Health and Medicine. Stem cells are one of the most promising cutting edge technologies in the health and medicine sector. We can estimate the impact on human lives through the myriad treatments stem cells offer for serious diseases:

- **Chronic Kidney Disease** affects the blood filtering process of the body and there is no cure for any of the **850 million** annual patient [5].
- **Leukemia** is a serious type of blood cancer which is treated through bone marrow transplants (in addition to other cancer measures). However, there is a significant shortage [number?] of bone marrow donations compared to the **500,000** annual patients [6].
- **Parkinsons** is a neurodegenerate disorder causing the **8.5 million** annual patients to loose control of their movements [7].
- **Cardiovascular Diseases** are one of the leading causes of death globally with an annual fatality rate of **17.9 million** people [8].
- **Autoimmune Disorders** cause the bodies immune system to attack itself, again a disease without a cure, affecting 4% of the population which amounts to **315 million** people [9].

These are just some of the diseases whose treatments could be revolutionised through stem cell therapies, and we can see that making stem cells available for medical use can impact **a billion** people.

However, the impact is bounded by the number of people who can access the treatments. That is why our LSD Micro-Bioreactor is designed to be cheaper and more autonomous, allowing it to be used in hospitals across the socioeconomic spectrum. Globally there are an estimated **8.6 million** excess deaths due to poor health care in lower economically developed countries [10]. But health care inequality is an issue that affects more economically developed countries too. Currently, 800 million people spend more than 10% of their income on medical bills, putting them in serious risk of falling into poverty [10]. The LSD Micro-Bioreactor will ensure that people aren't left behind when cutting edge medical revolutions improve and save peoples lives.

In 2022 the global stem cell market was worth **13 billion $** with a forecasted growth of 10% by 2030 [11]. The global bioreactor market was **3 billion $** in 2020 with an estimated growth of 11% by 2030 [12]. These are immense markets in which our application can tap into a pool of existing funds.

7 Individual reflections

7.1 Yiyuan Chen

The CERN Ideasquare Summer School undoubtedly marked a once-in-a-lifetime experience for me. My initial expectations were challenged when I first entered the program, as I had anticipated a more technical project rather than a business and entrepreneurship oriented one. Despite my limited exposure to entrepreneurship projects, I swiftly adapted myself to be open-minded and learned to accept ideas about the innovation process. This experience expanded my horizons and provided invaluable insights into the innovation process.

The collaborative team atmosphere was particularly enriching. I am immensely grateful for the synergy within our team, where members listened attentively and fostered strong camaraderie. Each team member demonstrated commendable dedication, a quality I hold in high regard.

In the final days at CERN, I found myself truly awed by the remarkable facilities and thoroughly enjoyed the prototyping activities at Ideasquare. Engaging in meaningful conversations with peers and staff at CERN further deepened my understanding. Additionally, the group excursion to Geneva was a memorable highlight. I can definitely recommend this summer school to my fellow students.

7.2 Alysha Blömker

What impressed me the most throughout experience is the incredible learning environment that was created through my fellow students! Not only was it immensely enriching to have people from many different academic backgrounds, but the engagement and enthusiasm shown by almost everyone was contagious (in a good way). The main learning points I took away from the whole innovation process is: A) to talk to as many people as possible, every person has something valuable so say one just has to have the courage to ask; and B) to be rigorous in questioning our assumptions about the impact of an application, do people really -need- it, can it really have a ground breaking impact on society? It was also amazing to be in Geneva and to work on CERN grounds at the IdeaSquare. I think we were very lucky to have so many wonderful people from CERN around us. One point of improvement for the course would the time point at which we started actually working on the project with our teams. I would have preferred it if the lectures in Delft incorporated the start of the project work. Especially when wanting to contact as many experts as possible, we felt as though there was not enough time for us to get the most out of it.

7.3 Nassim Beladel

In all honesty, and I think many students might silently agree with me, I initially met the CERN IdeaSquare Summer School with some level of apprehension and scrutiny. After the programme was introduced to us, its explicit renunciation of a purely 'scientific' or 'engineering' mindset somewhat defied my earlier expectations of the programme, and slightly diminished my enthousiasm for its content. However, after having completed the programme, I can nonetheless claim that I found it incredibly educational and worthwhile, without hesitation. The creative environment of the IdeaSquare test facility, and the shared struggle to meet the deadlines allowed for the quick and strong establishment of friendship and a shared sense of pride in our efforts. Though I do believe the programme can yet be improved upon to provide a more cohesive and smooth experience, the premise and, largely, its execution nevertheless provide for a fun and exciting experience that has left me wanting for more. The conversations with academic and industrial experts were highly engaging, and the creative interchange between committed students creates a mentally stimulating environment that I thoroughly enjoyed. Even if none of the ideas may prove to be fruitful in the longer term, my engagement with the ideation process – from an abstract technology to a concrete product – shall prove to have been fruitful in my personal and professional development, for which I am very grateful.

7.4 Bartłomiej Grochowski

After the very first lecture of the 2023 CERN IdeaSquare Summer School in Delft, I had quite a clear view of this project. Forget about scientific breakthroughs, focus on making good use of state-of-the-art technologies. This was very well explained then, and it stuck in my head throughout the project. It simply felt like a different path then I first imagined, but I didn't feel disappointed. To be honest, I felt like it sounds like a

bit more challenge then I imagined, and I was right. The summer school itself was very intensive, more than I imagined. These days I had a quite underwhelming sleep schedule, which ment that at times I wasn't as productive as I hoped to be. Nevertheless, I think that this experience taught me a lot. I feel like knowledge learnt in the university degree is very important, but this sole knowledge wouldn't lead towards a much better future. Of course we learn how to make some impact, but how to measure and assess it? How our designed would do on the market? How to be sure our ideas are as good as possible, and how to come up with original ideas that are out of the box? These questions were answered during this summer school, and I think it closes the bridge between "good engineer" and "successful engineer able to change the world". A truly mind-opening experience!
P.S.: This edition of the summer school wouldn't be as great without all the fellow participants! We had fantastic time in Geneva, I felt like we integrated a lot, and made friendships that are very likely to last :)

References

[1] Carlos AV Rodrigues et al. "Stem cell cultivation in bioreactors". In: *Biotechnology advances* 29.6 (2011), pp. 815–829.

[2] Elisa Figallo et al. "Micro-bioreactor array for controlling cellular microenvironments". In: *Lab Chip* 7 (6 2007), pp. 710–719. DOI: `10.1039/B700063D`. URL: `http://dx.doi.org/10.1039/B700063D`.

[3] Tiago G Fernandes et al. "High-throughput cellular microarray platforms: applications in drug discovery, toxicology and stem cell research". In: *Trends in biotechnology* 27.6 (2009), pp. 342–349.

[4] Andrijana Bolic. "Development and application of a milliliter-scale bioreactor for continuous microbial cultivations". English. PhD thesis. 2018.

[5] Csaba P. Kovesdy. "Epidemiology of chronic kidney disease: an update 2022". In: *Kidney International Supplements* 12 (Apr. 2022), pp. 7–11. DOI: `10.1016/j.kisu.2021.11.003`. URL: `https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9073222/`.

[6] Mengbao Du et al. "The Global Burden of Leukemia and Its Attributable Factors in 204 Countries and Territories: Findings from the Global Burden of Disease 2019 Study and Projections to 2030". In: *Journal of Oncology* 2022 (Apr. 2022). Ed. by Irena Ilic, pp. 1–14. DOI: `10.1155/2022/1612702`.

[7] *Parkinson disease*. www.who.int. URL: `https://www.who.int/news-room/fact-sheets/detail/parkinson-disease#:~:text=Global%20estimates%20in%202019%20showed` (visited on 08/31/2023).

[8] WHO. *Cardiovascular Diseases*. World Health Organization, 2022. URL: `https://www.who.int/health-topics/cardiovascular-diseases#tab=tab_1` (visited on 08/31/2023).

[9] *Autoimmune Disease*. National Stem Cell Foundation. URL: `https://nationalstemcellfoundation.org/glossary/autoimmune-disease/` (visited on 08/31/2023).

[10] *Half the world lacks access to essential health services – UN-backed report*. UN News, Dec. 2017. URL: `https://news.un.org/en/story/2017/12/639272-half-world-lacks-access-essential-health-services-un-backed-report` (visited on 08/31/2023).

[11] *Stem Cells Market Size, Share Trends Report, 2021-2028*. www.grandviewresearch.com. URL: `https://www.grandviewresearch.com/industry-analysis/stem-cells-market` (visited on 08/31/2023).

[12] *Bioreactors Market Size and Growth Analysis By 2030*. Allied Market Research. URL: `https://www.alliedmarketresearch.com/bioreactors-market` (visited on 08/31/2023).

A 100 industry sectors for AHEAD technology

1. Environmental Monitoring [29, 30, 31]
2. Oceanography [1, 3, 11]
3. Chemical Industry [9]
4. Oil and Gas Industry[2]
5. Automobile Industry [15, 19, 23]
6. Aviation Industry [21, 27]
7. Space Industry [18]
8. Shipbuilding [22, 28]
9. Defence Industry [20, 26]
10. Data Centers
11. Computer Industry [13, 44]
12. Semiconductor Industry [46]
13. Robotics [12, 59]
14. Batteries [24]
15. (Energy Generation)
16. LED Industry [45]
17. Electronic Components Industry [35]
18. Art Conservation [34, 37, 38]
19. Architecture
20. Building Materials [36]
21. Infrastructure Operations
22. Water Management Systems [17]
23. Urban Waste Management [32, 43]
24. Industrial Waste Management [42]
25. Waste Processing
26. Water Quality Control [4]
27. Biomedial Engineering [52, 53]
28. Medical Industry [54, 55, 56, 57, 58]
29. Pharmaceutical Industry [10]
30. Laboratory Equipment [41]
31. Scientific and Technical Instruments
32. Environment Systems for Buildings [4, 39, 40]
33. Industrial Temperature Regulation [14]
34. Food Processing Indsutry [7, 8]
35. Food Storage [35]
36. Horticulture [16, 33]
37. Aquaculture and Fishing Industry
38. Wood Industry (Forestry)
39. Landscaping
40. “Simulations” [47, 48, 49, 50, 51]
41. 3D Printing [6]
42. Commercial Printing
43. Construction Engineering
44. Education
45. Hospitality
46. Restaurants
47. Steel Industry
48. Textile Industry
49. Film Industry
50. Offshore
51. Ore Mining
52. Exploration Geology
53. Telecommunications
54. Retail Industry
55. Fertiliser Manufacturing
56. Household Appliances
57. Courier and Delivery Services
58. Biotechnology
59. Amusement Parks
60. Public Transport
61. Packaging and Containers
62. Cosmetic Industry
63. Commercial Real Estate
64. Sports and Sport Equipment

65. Commercial space-fare
66. Paints manufacturing
67. Biofuel production
68. Science museums
69. Interior design
70. Space exploration
71. Dairy production and processing
72. Terraforming planets
73. Commercial heating systems
74. Commercial refrigeration systems
75. Plastics and polymers
76. Crypto mining
77. Security/Anomaly detection
78. Maritime
79. Animal care
80. Fashion design
81. Music production
82. Superconductor industry
83. Quantum computing industry
84. Particle colliders
85. Material science industry
86. Green energy industry
87. Tourism
88. Neutrino detectors
89. Power plants
90. Aquariums and zoos
91. Paper mills
92. Recycling facilities
93. Nuclear reactors
94. Dentistry
95. Supercomputing
96. Therapy
97. Gravitational wave detectors
98. (Public) Central heating systems
99. High-frequency trading
100. Arts industry