Progress Report

Eunkyung Cho, Adan Rotteveel, Blas Loyens, Lohithsai Yadala Chanchu

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Contents

Team Composition

The team was composed of four members, though there was briefly a fifth member who dropped out/could not attend the sprint days. The members were namely: Adan Rotteveel, Blas Loyens, Eunkyung (Jennifer) Cho and Lohithsai Yadala Chanchu. This was the first time this diverse group of students from TU Delft and UvA with different (technical) backgrounds have collaborated with one another. We have below a short introduction from each member.

Adan Rotteveel
Adan Rotteveel is currently pursuing a bachelor's degree in Artificial Intelligence at the University of Amsterdam (UvA). His introduction to this summer school came after attending the honours 3D prototyping course, which sparked his interest in the integration of technology and education. Adan's main areas of interest lie at the intersection of AI and medical applications. He believes that with the right application, AI has the potential to revolutionize medical diagnostics, treatment, and even patient care. Furthermore, his fascination with physics drew him towards the CERN Summer School.

Blas Loyens
Blas Loyens is a second-year student at Delft following the double major Applied Physics and Applied Mathematics programme. Naturally, his interests in Physics led him to pursue intereset in the CERN summer course, which he was made aware of through the Honours programme at Delft. His honours work intersected quite a few fields, on the topic of quantum computational approximations. In trying to ensure a more varied education, he signed up for the innovation-creating aspects of the summer course. Whilst the breadth of his knowledge allows him to come up with novel ideas, he can sometimes be a bit timid in expressing these ideas.

Eunkyung Cho
Eunkyung Cho is a third-year Aerospace Engineering student at Delft University of Technology in the Netherlands. She is part of the Honours programme and is currently researching the influence of changing chord length in ice accretion formation and its effect on fixed-wing unmanned aerial vehicles' aerodynamic performance. In addition to this, she is currently on an

exchange to Nanyang Technological University in Singapore to experience and explore various cultures by interacting with various individuals with diverse backgrounds.

Eunkyung joined the summer school because she wanted to apply the expertise gained in Aerospace Engineering in a new context. As a second-year aerospace engineering student who only learned it for one year, she did not have a lot of opportunities to apply the knowledge. Additionally, applying the knowledge she gained from education is the goal of her education career. Therefore, she joined CERN summer school with great enthusiasm.

Some of the things Eunkyung brings to the table are honesty and knowledge within the field of aerospace engineering. Her honesty led to trust among the team members which led to more open communication. However, this also has drawbacks which are inadvertently hurting others' feelings.

Lohithsai Yadala Chanchu

Lohith is studying Computer Science and Engineering at Delft University of Technology. He has always had an interest in building things that people find useful, which was primarily the reason he chose Computer Science as his major. He was introduced to this summer through his faculty's honors program, where Lohith is currently researching polarization-based drone navigation. Lohith's main areas of interest lie in identifying people's needs and wants and building solutions for them. Some of the skills Lohith brings to the table include the ability to adapt ideas based on feedback, an understanding of software systems and their construction, and efficient communication within group environments.

1 INNOVATION PROCESS

When we first established our team, we laid out a few ground rules to ensure a collaborative and productive environment. These ground rules capitalized on our strengths and mitigated our weaknesses, which we also discussed on the first meeting on the 1st of June 2023. The ground rules that the team agreed upon were as follows:

- Be an active listener when others are talking
- Take accountability for your actions
- Provide constructive feedback
- Respect each other - both in terms of opinions but also critically in terms of their time
- Remain open-minded to new ideas

1.1 Technology Unbundling

After familiarizing ourselves with each other and establishing the ground rules for collaboration, the team was assigned the technology **HYLIGHT**. Some short slides were provided giving a brief description of the technology, its purpose and its applications. Right from the onset we knew that we were dealing with a very technical device, which initially posed a few complications to the technology unbundling process. Our priority was to understand the technology and to strip down the device to its core - the new technology that it brings - to answer the question "We know how to" about our technology.

We were initially a bit misled with the introductory slides of our technology, which presented itself as a uterus direct imaging technique for IVF clinics. The specificity of the technology blindsided us to think mostly within the context of embryo development in the first few meetings in June, with our answers to "We know how to" reflecting this:

- Determine the metabolism of cells with a non-invasive process
- Determine embryo health based on the metabolism

Whilst the context was limited, it was clear that our technology had potential for uses within the biological domain.

On the 22nd of June 2023, we realized the true technology at the core of this imaging technique, in one of our first eureka moments. We had identified the use of a hyperspectral camera which enabled HYLIGHT to be quick, efficient and non-invasive. Further research into these cameras allowed us to develop a deeper understanding of the technology. Whilst these cameras were commercially available, they were only in circulation recently, so they were still ripe to be applied innovatively into new domains.

Armed with this new information, we set up a meeting with Anna Ferrer Vaquer, the project manager for HYLIGHT. During the meeting, we sought specific details on how the technology is good at what it does, and in particular the numerical benefits of using hyperspectral imaging instead of other imaging techniques (e.g. is hyperspectral 10× better at identifying compounds compared to, say, multispectral?). With the information we gained from the meeting, we could more accurately assess the potential of the technology, and we had developed a list of insights for the technology, namely:

- The size of the HYLIGHT setup is 1.8m×0.9m, but the commercial product will likely be in the 30cm range
- Each scan takes about 10-20 seconds, with a trade-off between resolution and speed of detection that can be adjusted for differing contexts
- The HYLIGHT setup makes use of a novel machine learning algorithm to determine how different markers of metabolic activity can correspond to embryo health
- By changing the optical setup, it is possible to achieve different imaging sizes, from the microscopic level, to the macroscopic level

Nonetheless, we only successfully managed to fully understand the core of the technology, the hyperspectral component, during the 3-day Design Spring at Delft (10-12th July, 2023). Namely, on the 11th of July, we had a meeting with a hyperspectral expert who was using the technology in a different biological context . This expert was Mark Witteveen, a PhD student at the Netherlands Cancer Institute, who was trying to use the hyperspectral imaging for detection of cancer cells during surgery. He provided with us a very good insight for the full scale we

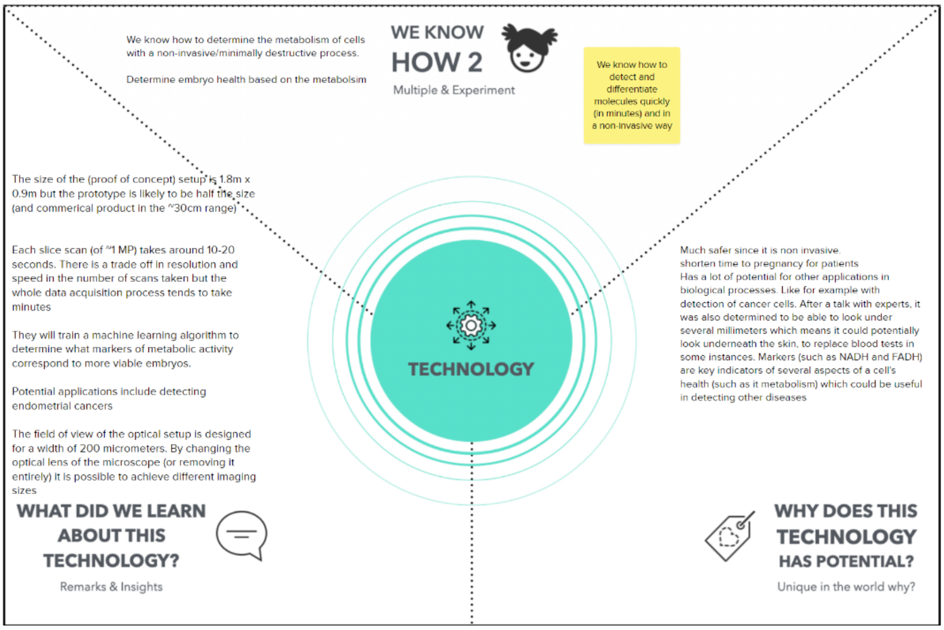

Figure 1.1. Our filled in technology unbundling canvas, after meeting with the HYLIGHT researcher

could achieve with our technology, and pointed out very clearly the limitations & applications. In the end, we felt that we could confidently answer the "We know how to" with something that did not pertain to embryos or cells - namely:

We know how to detect and differentiate molecules quickly and in a non-invasive way

The expert also answered a lot of questions we had with regards to the next crucial phase of the innovation process, namely...

1.2 Domain exploration

In order to apply the technology to something new, we needed to broaden our horizons by determining all the possible domains where HYLIGHT could have an impact, even if a marginal one. Nonetheless, our first draft of the brainstorming session on July 10th, 2023 was still heavily centered around the context of medicinal applications, in particular IVF. It was only after the aforementioned meeting with the hyperspectral expert that we determined the full potential of the technology, from the microscopic level - this time not just for biological compounds - to the planetary level. In the end, we managed to determine 100 domains/subdomains where HYLIGHT and its novel hyperspectral imaging technology could be used. We had not conducted a lot of research to determine these domains, to encourage out-of-the-box thinking. However, from these domains, we selected 25 and divided it amongst the 4 team members to do a rapid

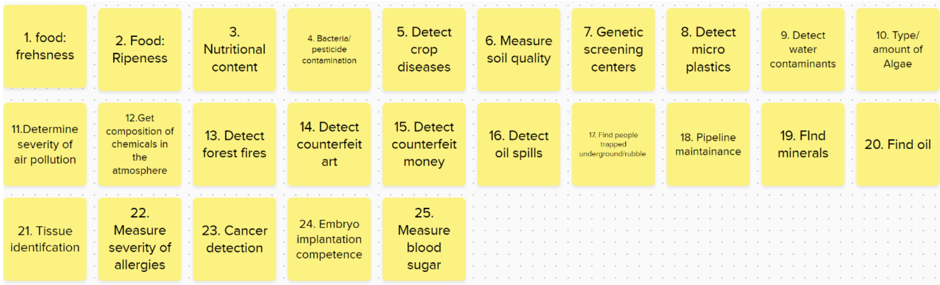

Figure 1.2. The 25 subdomains we conducted further research on

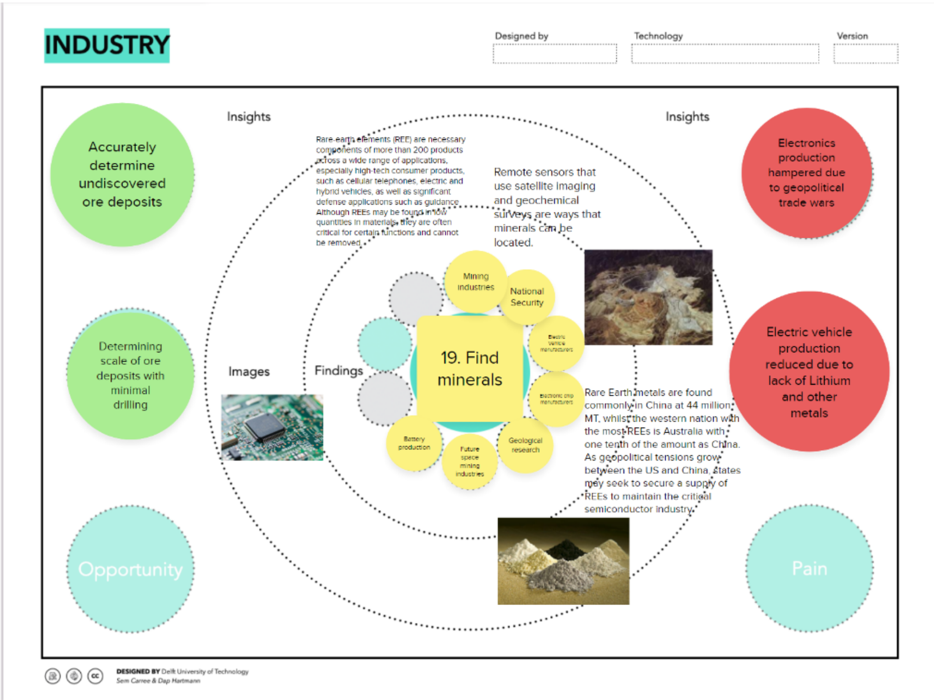

Figure 1.3. An example of the subdomain research we conducted

round of research. This research included: determining the subdomains, affected organizations/customers, the pains that they are experiencing that could potentially be solved with our technology, and the gain acquired by implementing our technology to their processes. In order to ensure we were not subconsciously ruling out potentially ground-breaking ideas, we had more brainstorming sessions, using visual techniques and applying our technology to popular movies. At this point, we had a handful of subdomains and ideas that looked promising, namely:

- Blood sugar detection, e.g. in a watch
- Localized chemical detection - by installing HYLIGHT onto satellites to determine e.g. factory compliance to (air) pollution laws
- Natural disaster detection - again from a satellite, to then provide fire services a rapid

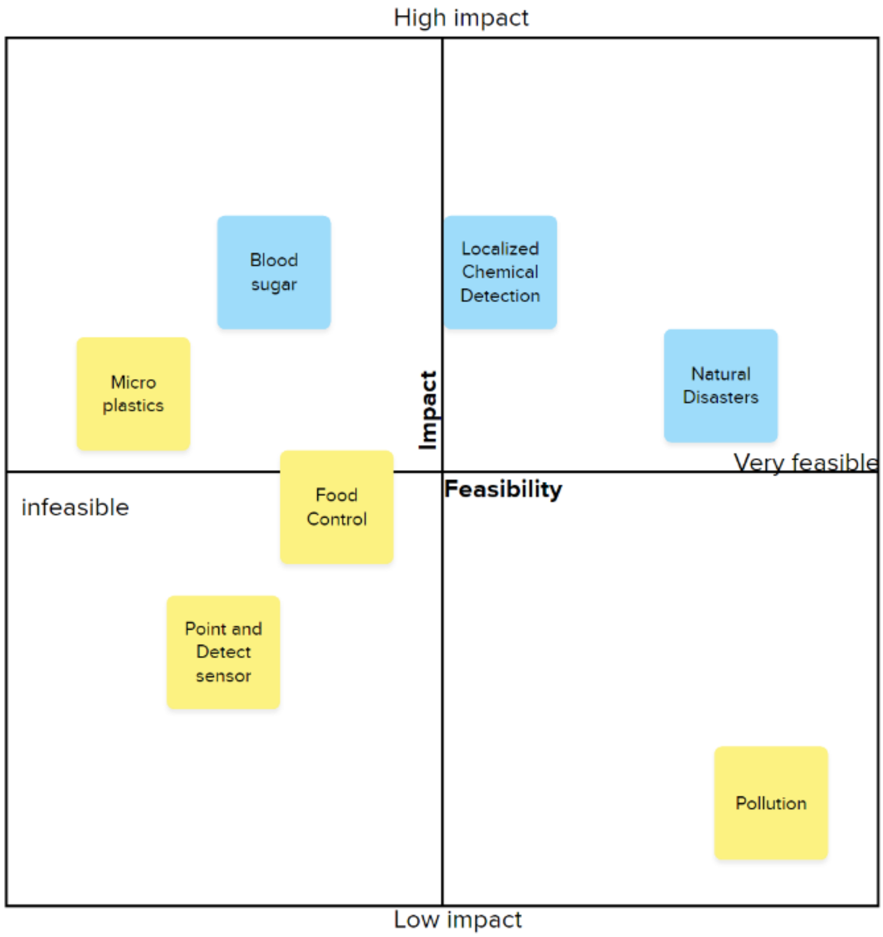

Figure 1.4. The 7 promising technologies, evaluated on feasibility and impact - the blue ones were particularly promising

response to wildfires before they balloon out of control.

- Food control - either at the supermarket level to determine the ripeness of foods and potential diseases, to the consumer level by providing grocers the ability to check food freshness
- Pollution detection - for example gas leakages from pipeline failures.
- Microplastic detection - either for governmental monitoring, or for personal consumer use.
- A point & detect sensor, for example to determine counterfeit art, or certain chemicals of interest.

We took these ideas and evaluated them based off of feasibility and impact, leading us to determine three ideas which we were particularly interested in.

We ensured to link our ideas with some of the UN Sustainable Development Goals (SDGs), both as an inspiration and an affirmation that we could use our technology to improve the problems plaguing the world. Finally, on July 12th 2023, we consolidated our research in the different subdomains and applications, evaluating the target audience, opportunities and potential applications for each of them. In order to further validate our choices, we made simple prototypes of the applications for each subdomain, allowing us to get a sense of scale and a first-hand view of any potential constraints.

1.3 Domain selection

Having brainstormed and evaluated a handful of potentially feasible, high-impact domains, we then put our efforts into researching further to determine which subdomain to pick. Our focus criteria for assess technologies was feasibility - is there a market, are people willing to pay, could it be done, does it actually fix anything - however we were not very rigid about how we assessed this, preferring instead to determine by consensus which subdomains to scrap on the basis of feasibility. Our preliminary research whilst going through the 25 domains mentioned earlier had led us to a complication. In a lot of these domains, hyperspectral imaging had been recently employed in order to bring about the gains that we had found earlier. For some domains, the implementation of the technology was still in the research stages (for example, for wildfire detection). But for others, there were already corporations that incorporated our technology into their product process, which means the only way we could improve is if we have an improvement of the technology itself, but such improvements tend to be small-scale (see, for example, improvements in successive diesel motor engines in the 2000s to 2010s) and not ground-breaking. As such, we would often assess for these subdomains that the cost of replacing their current infrastructure with our improved hyperspectral technology would not be sufficiently be offset by gains of the sort as, +2% detection speed.

We also aimed to contact more experts on the different subdomains to properly empathize with their pains and see if we can address these with our technology in the way we envisioned, or whether we need to adjust it in a different way. However, what we found that helped a lot in terms of determining feasibility of an idea was simply talking to individuals, and at CERN we had plenty of opportunity to discuss with both the IdeaSquare employees and visiting students, as well as the CERN engineers, interns and summer students at the cafeteria. These discussions, for example, helped us realize that the idea of a blood sugar watch is not necessarily novel, and we would have to use our technology in a way that detects more than blood sugar to bring back the innovative edge - the unfair advantage - over current commercial models of health watches.

They also made us appreciate what made HYLIGHT so special - that you could detect a whole array of molecules, even ones you weren't looking for, with a camera.

With this in mind, our team came to a consensus and struck down the vast majority of the aforementioned subdomains. As we were quite engrossed in research, we had found a new domain that had eluded us - namely in the waste management industry. This led us to repeating a little bit of the aforementioned processes on this new domain - finding subdomains, determining the pains and gains for each, and then determining the feasibility of using our technology to improve the process. In the end, we had determined that the well-known problems of e-waste management could potentially be lessened with our technology. There are well documented landfills in developing economies filled with e-waste, often from across the world. The problem with electronics (and its waste) is that there are many different compounds, metals and elements used in the making of different circuitery, some of which is totally harmless, some of which is toxic and all of which is glued and assembled together into a machine - and so difficult to separate. Identifying such materials seemed to be the first step in the separation process, and this is exactly where HYLIGHT excels in. So we had determined that we would use the technology in the context of e-waste identification - an idea that can be tangentially linked to pollution detection and localized chemical detection in the list of 7 promising subdomains in the previous chapter.

2 Problem and Solution

2.1 Problem

The majority of the waste we discard does not undergo recycling. Instead, a significant portion is squandered within landfills situated in underdeveloped nations, where hazardous waste items like batteries deteriorate, adversely impacting local communities by contaminating both air and soil. Attempts to address this issue are made by local governments through the examination of landfill waste samples, soil samples, and the air quality surrounding these landfills. However, executing these measures effectively proves to be time-consuming, costly, and poses health risks for inspectors. Furthermore, these tests just indicate that there is a leakage present but it doesn't provide information such as the source of the leakage which would make cleanups much faster and less expensive.

Inspectors have to physically travel to the landfill sites to collect multiple samples, which are subsequently sent to laboratories for analysis, with results becoming available weeks later. Moreover, these inspections are primarily conducted in economically developed countries, whereas their occurrence is less frequent in underdeveloped nations due to their associated expenses. This lack of inspection prevalence is concerning, as underdeveloped countries possess the most landfills, resulting in limited knowledge about the extent of pollution's impact on the majority of the population.

Given their high costs, inspections in underdeveloped countries are infrequent or altogether absent, allowing harmful chemicals to spread over wider areas, contaminating rivers, livestock, and the population.

2.2 Solution

User Story

The proposed alternative to the problem outlined above is the following: The environmental protection agency (more specifically the ones in charge of soil and water quality) purchases several units of MAP-E, which is a rover that has the ability to identify materials visually with an attached drill fibre-optic cable that allows it to see beneath the surface, along with the relevant mapping and data-visualisation software. The agency can send these rovers (manually) to the landfills that are recommended by the software system, which takes into account when it was last mapped, number of nearby landfills, and potential geographical risks (like being close to a river). Once on a landfill, these rovers act autonomously to take paths that efficiently map the contents of the landfill, and also the area around it. It will consistently map the coordinates, depth, amount, and type of materially using its hyperspectral camera and optic fibre drill. The rover will constantly be mapping the landfill except when it goes to charge, during which the obtained data can be shared with the agency. The agency can use the data-visualisation tools to easily see the contents of the landfill through a 3D depth and colour map of the landfill, with especially toxic substances being brought to attention. In the event, a toxic chemical is detected leaking from the landfill, the agency can extract the source quickly (since they know the location) before it causes further contamination.

Advantages of MAP-E

Government agencies responsible for ensuring water and air quality will have a much more up-to-date idea (compared to the current way) of the contents of landfills and thus can be alerted to potential leaks quicker, reducing the time the contaminants have to spread.

Once a leak is detected, the source can be easily and quickly determined (using the data visualisation tools of the contents of the landfill), allowing it to be removed quicker than having to perform another search for the source after detecting the leak.

Recurring salaries for highly-trained inspectors who are willing to take the risks of being exposed to contaminated substances are likely to cost more than a one-time purchase of MAP-E over its life-time. This is not to mention that using rovers instead of inspectors also eliminates the health risks posed to the people who are actually collecting the samples.

3 Impact and Market Opportunities

In this section of the report, the potential impact and market opportunities are discussed. With the increase in the use of electric devices, e-waste disposal has become a pressing concern. Therefore, a lot of research has been done and using the previous study material, the potential impact of MAP-E was deduced and presented in this section.

According to the United Nations University E-waste Global Monitor which was conducted in 2020, 53.6 metric tonnes were generated in 2019 worldwide and the figure is expected to grow every year Igneo, n.d. This is equivalent to 7.3 kg of e-waste per person in the world, but only 17.4% is presently recycled, revealing substantial unrealized business potential.

Remarkably, the unrecycled e-waste contains valuable materials worth $57 BN such as gold, platinum and other high-value recoverable materials. This represents an enormous market opportunity for companies involved in e-waste recycling.

It not only presents market opportunities but also makes a substantial contribution to fostering a more sustainable approach to the use of electronics. The presence of highly toxic chemicals like lithium, cobalt, and other heavy metals makes e-waste a notable ecological threat. If these hazardous substances leach into the soil and groundwater, they can contaminate the entire environmental ecosystem, potentially causing severe health issues such as cancer or waterborne diseases. Not only that but, the batteries in landfills that are not fully discharged can lead to fire hazards and the emission of various toxic gases.

4 Individual Reflections

Adan Rotteveel

Joining the CERN summer school, I was both eager and unsure of what to expect. A major takeaway for me was understanding the importance of practical solutions over just innovating for the sake of it. Time constraints posed challenges, and I found it hard to juggle between workshops and focused work. Our team, made up of diverse individuals, collaborated effectively and brought different strengths to the table. The experience taught me the importance of standing out and doing something unique. While I appreciated the program, it often felt more business-oriented than I anticipated. I would recommend it to others, but I think it could benefit from a clearer structure.

Blas Loyens

I joined the CERN experience to get a hands-on experience on the innovation process that's behind a lot of common products, and to see for myself why CERN is a center of research and novel technologies. After the summer course, I can confidently say I managed to achieve these goals and so much more. Though at times the situations were stressful, due to the short-term nature of the summer course, I still felt as though our team and I successfully managed to overcome the challenges. I felt as though my creativity got stretched and I understood the importance of collaboration, both within the team and outside it, to bring out the best ideas. I definitely feel like I've learned a lot, and I do recommend the course to other students, although with the way it is designed and structured, it's not for everyone.

Eunkyung Cho

"The whole CERN summer was an unforgettable experience in my lifetime. The most valuable takeaway was gaining confidence in sharing my ideas. The summer school provided me with a collaborative environment, which necessitated interactions with peers from diverse backgrounds and various experts. This forced me to get out of my comfort zone. Before participating in this CERN summer school, I often hesitated to present my ideas unless explicitly required. However, the school demanded active participation leading to active participation in class. Although initially challenging, sharing ideas with others became more and more natural as the program progressed. The summer school led me to overcome and improve my weakness, leaving a lasting impact.

In addition to this, I also gained a wealth of knowledge in various fields. As explained in the previous sections of the progress report, our technology was hyperspectral imagining. During the process of finding its application, I had a great opportunity to learn what it does or what is it about in depth. Besides this, I could develop multi-perspective thinking skills by being in multidisciplinary teams. As all the team members had different backgrounds, we could approach a problem from various perspectives which led me to develop new skills.

Overall, I gained a lot of things from this summer school such as new knowledge/skills and nice people. Throughout the course, my team faced challenges as well but I believe our team managed to complete the project well. I personally enjoyed this experience very much and I can highly recommend other honours programme students to take the CERN HPD course."

Lohithsai Yadala Chanchu

The entire CERN HPD summer school marked a truly exceptional experience for me. The opportunity to bring real-life applications to technologies developed at CERN, an environment that had seemed somewhat distant due to my computer science background, was an invaluable experience. Collaborating within a technical team and learning to make decisive choices under time constraints during idea formation was a valuable skill.

The interdisciplinary nature of the team, coupled with the course's immersive idea-generation techniques, was instrumental in solidifying our group dynamics and producing innovative ideas. The challenging moments we encountered only served to enhance our problem-solving abilities. Additionally, the camaraderie among the team members and the shared dedication to our project created an encouraging atmosphere.

In conclusion, the CERN HPD summer school offered a transformative experience that expanded my horizons and provided hands-on insight into fast-paced technical work. I would recommend this course to others without hesitation and eagerly await the remarkable projects that future participants will produce.

Bibliography

Igneo (n.d.). *E-waste recycling*. URL: https://www.igneo.com/.