3 SALUD Y BIENESTAR

TEAM MARIE CURIE

CBI Challenge Based Innovation

FALL 2022

LUMO

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1. RESEARCH REPORT: UNDERSTANDING THE PROBLEM

We started off with the challenge of tackling SDG #3 - Health & Wellbeing. After having an intensive kick-off week and listening to plenty of speakers, we started to form an initial hypothesis and general idea of the challenge we wanted to tackle. We knew that the Attract imaging technologies had applications that would be useful for cancer. That led us to our initial direction of focusing on cancer. Our first hypothesis was to go in the direction of early detection. To first understand more about cancer and how it is tackled in Spain, we started with desk research. We researched information on the following topics:

- Prevalence of Cancer in EU
- Cancer in Spain
  - Most deadly types
  - Most common types
- How is Cancer Detected & Diagnosed
- Existing technologies & Initiatives
- Radiotracers: how are they used?

Once we had a bit more ground research, we focused on our interviews to give us more context. We conducted several interviews with oncologists, patients, and radiology experts. Each was helpful in its own way. A few people who gave us key insights and helped shape the direction of our project are the following:

C.S.
Breast Cancer survivor

"I traveled 2 hours from my home town to Barbastro and sometimes I couldn't even get treatment because my vitals weren't strong enough. At the end of the day, I would have to return without any treatment." This was one of our key insights throughout the journey - that she had to take an "ambulance bus" to a hospital to get treatment. Although the drive itself is only around one hour, her experience was significantly worsened by having to rely on this bus for her to travel a far distance for treatment. She might lose an entire day, and not even receive the treatment she needed. This was a corroborating statement to our hypothesis that access to treatment was inadequate.

Yolanda Sanz

Psycho Oncologist AECC

“The distance to hospitals is an added difficulty in rural areas for cancer patients”, *“There should be the same type of machinery in at least one hospital in each province. Therefore, it won’t be necessary to make such a long trip for a short test.”* This also confirmed our hypothesis that smaller hospitals in Spain don’t have the adequate tools they need to provide certain types of care.

Mara Cruellas

Oncologist at La Vall d'Hebron

“COVID caused a big delay in cancer diagnoses during the peak of the pandemic and there is still an evident delay in early detection. Many patients, when they are diagnosed, have already passed the curable phase, and the treatment is much more problematic.“ This told us that because of the structural problems in the healthcare system in Spain (specially during the pandemic), people were learning about the status of their cancer at much later stages which had a significant impact on the stage in which cancer was detected or treated at. This confirmed the hypothesis that there was a clear need for improving accessibility to tools that would help a patient monitor their cancer.

Dr. Josep Munuera

Specialist in neuroradiology

Dr. Munuera told us how using radiotracers for early-detection was a terrible idea. First because injecting someone with radiotracers exposes them to radiation, which can even trigger cancer. He pointed us in the direction of using the POSICS-2 technology for follow-up care, since it would be less risky to use radiotracers on someone who already has undergone cancer and cancer treatment.

Mercé Ginjaume

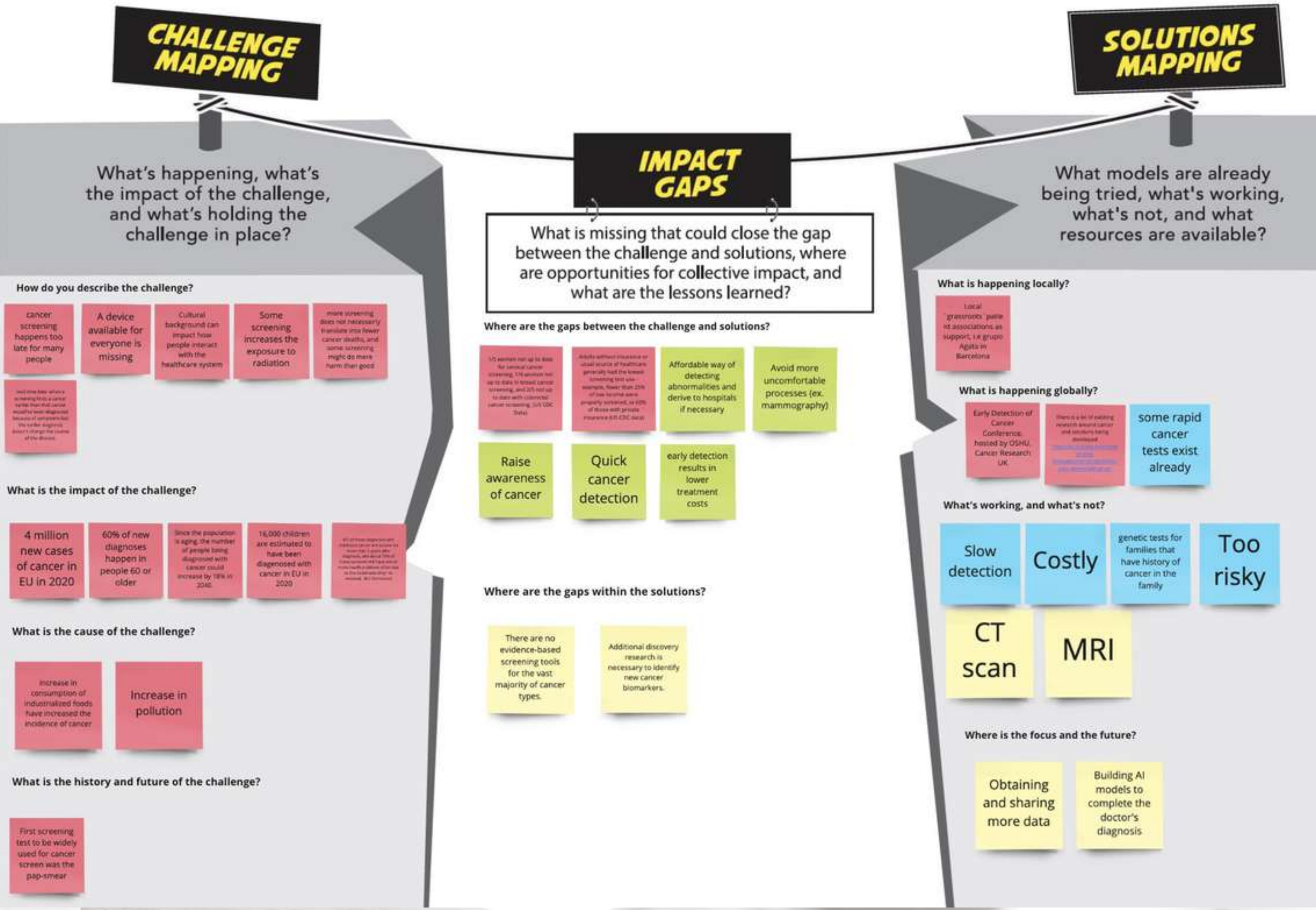
Radiology Expert

Mercé clarified for us the regulations around transportation radiotracers in Europe and the legislations behind it. This helped us better understand the system around being able to implement our solution, as POSICS-2 is reliant on radiotracers to function.

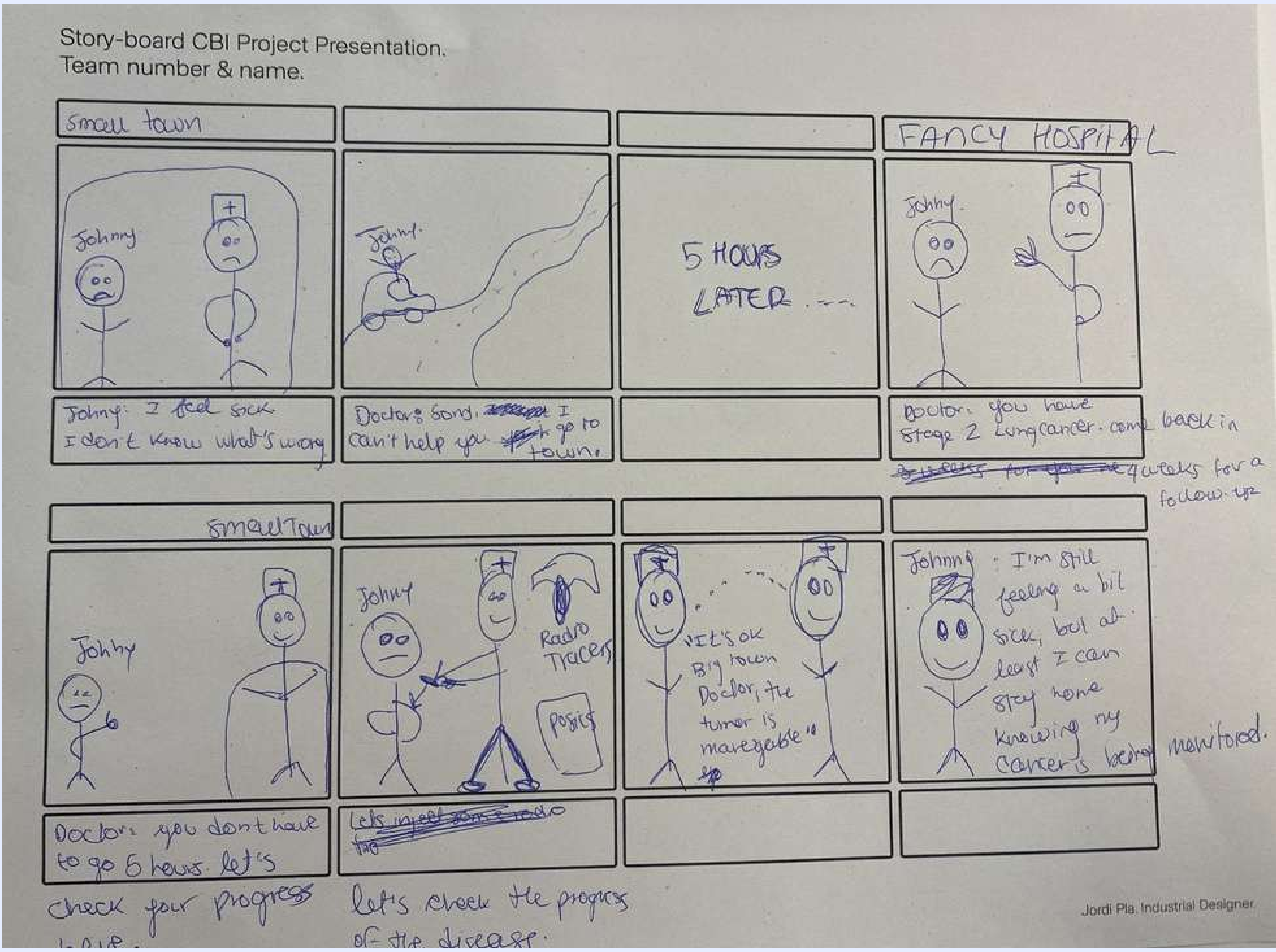
In tandem with executing desk research and interviews, we also worked through a few frameworks to gain different perspectives on our problem. These included an Impact Gap Canvas, Stakeholder Mapping, Storyboarding, and many others. See the following images for reference. The impact gap canvas was a useful and structured way to identify what was currently being done related to our problem so that we could then build on the solution. However, probably the most useful exercise was iterating through different versions of the storyboard. This led us to design the patient and doctor journey in different ways, which was quite useful in understanding our problem.

The people and connections maps helped us order our interviews and make sure we covered all the areas: doctors, organizations and patients at different levels. Thanks to this, we could have different points of view on the subject and go deep into the problem.

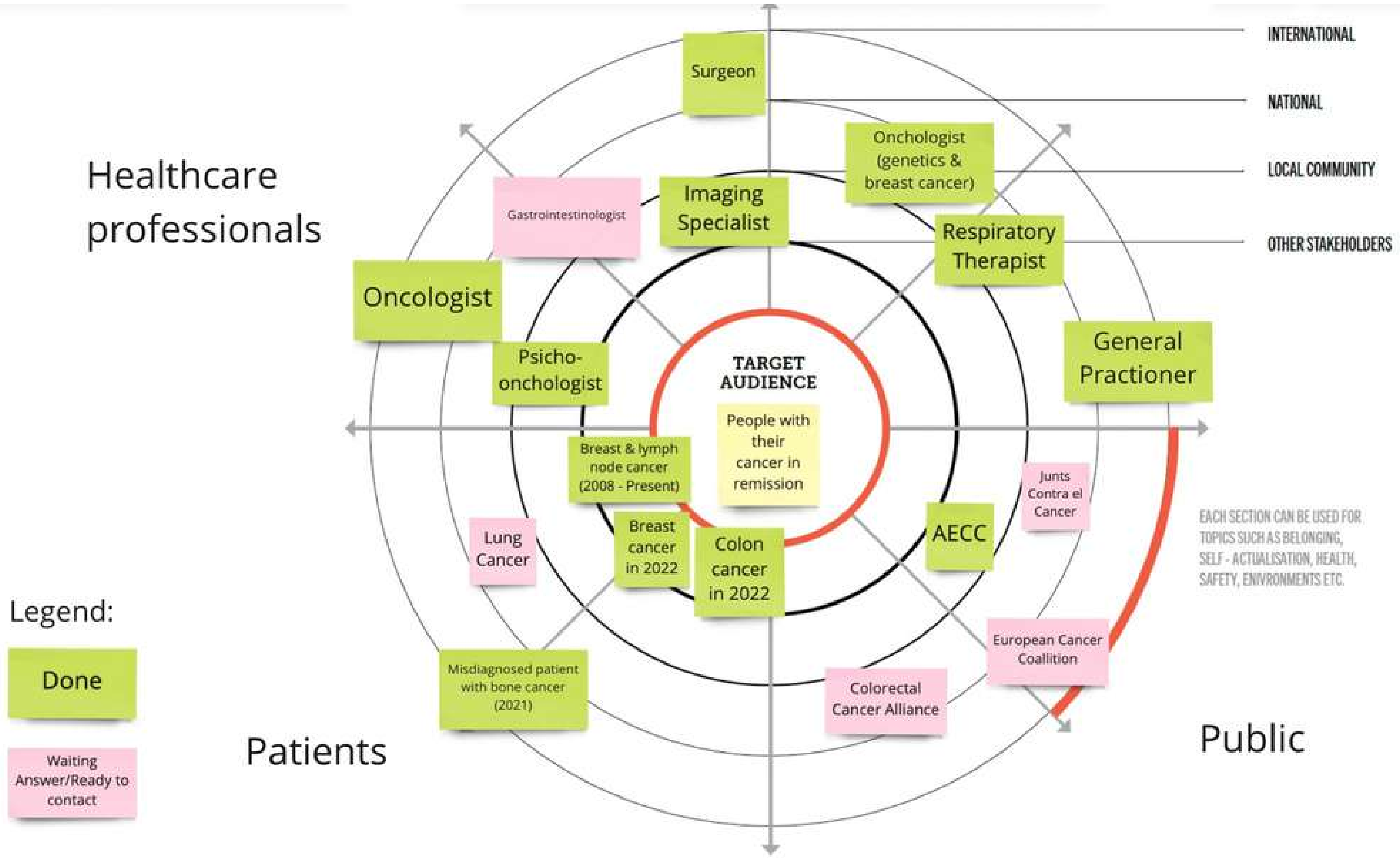
1.1 IMPACT GAPS CANVAS



1.2 STORYBOARD



1.3 PEOPLE AND CONNECTIONS MAP

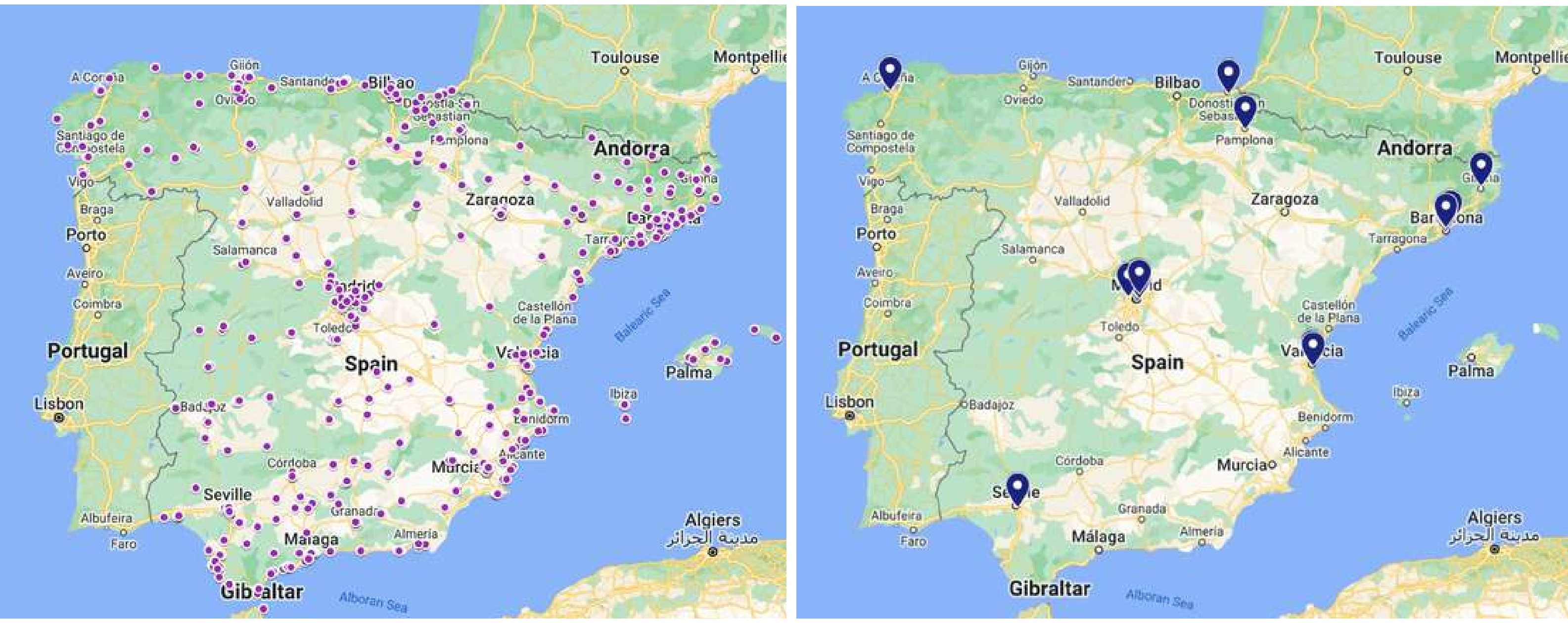


1.4 LIST OF INTERVIEWEES

Interviewee	**Role**	**Relevance**
Dr. Mara Cruellas	Oncologist	Medical oncologist, researcher in the hereditary cancer group at the Vall d'Hebron Institute of Oncology.
Dr. Tariq Khenkar	General Practitioner	In patients' experience.
Dr. Abdullah Mazrou	Family Doctor	Out patients/Screening Experience.
Dr. Jameel Rouwahi	Surgeon	Takes part in tumor removal surgeries.
Dr. Marta Picón	Respiratory Doctor	In patients lung cancer treatment.
Dr. Josep Munuera	Specialist in neuroradiology	Involved in our project since the beginning. It helped us understand the importance and use of radiomedicine in scanning.
Dr. Namrata Chigurupati	Oncologist	Oncologist with experience in hospitals in India.
Mercè Ginjaume	Senior researcher at UPC	Part of the Institute of Energy Technologies. Expert in Radiology Legislation.
Yolanda Sanz	AECC	Psycho - Oncologist of the AECC in Sabiñánigo, Alto Gállego y Sobrarbe (rural areas)
	Patient of a rural area	Breast cancer in March 2022. Currently in the follow-up phase.
	Patient of a rural area	More than 10 years with cancer/metastasis and involved in clinical trials. Inside AECC since the creation of her group.
	Patient	Colon cancer patient
	Patient's Family	

2. CONCEPTUAL DEVELOPMENT: FINDING A SOLUTION

After a patient is diagnosed and treated for cancer, they have to visit their doctor every 3-6 months for follow ups, including blood tests, physical exams, and many times CT/PET scans. Although there are 833 hospitals distributed around Spain, there are only 24 specialized in cancer treatment, and this complicates the access to those people who aren't living in big cities.



Distribution of hospitals in Spain vs distribution of cancer specialized centers.

We aim to propose a way to bridge this gap by providing a solution that will allow smaller regional hospitals in all of Spain to provide better cancer care, improving its access to those people living in rural areas (one out of ten people). This way, no one would have to drive more than 1 hour to receive the cancer care they need.

Besides, since the check-up visit is done until the results have arrived it can take up to 45 days. This results in uncertainty, stress, and nerves both in the patient and in his/her family. It is proven that one in three people with cancer experience mental or emotional distress.

In order to tackle this problem and find an adequate and coherent solution, we decided to start observing how current imaging techniques worked. Three parts can be easily differentiated: the logistics of radiopharmaceuticals, the scanning and the visualization of results.

2.1 LOGISTICS OF RADIOPHARMACEUTICALS

Radiopharmaceuticals are sensitive materials linked to strict procedures. As a result, they have to be manipulated by professionals with proper certifications and in certain conditions. Besides, they are specially produced for each patient and can only be used during a limited period of time, which increases the difficulty of the process.

As our aim was to involve remote, second type hospitals into the process, one important step towards achieving our solution was deciding how to transportate radiopharmaceuticals.

In order to improve accessibility, we had to address the issue of how to move radiopharmaceuticals. At first we thought about generating them at those hospitals with available cyclotrons, and distributing them around those hospitals nearby in an average car/truck owned by the company or the proper hospital. Thinking in future scenarios, this idea improved towards the use of drones instead of cars. This technique would allow us to distribute radiotracers quicker, avoiding traffic jams.

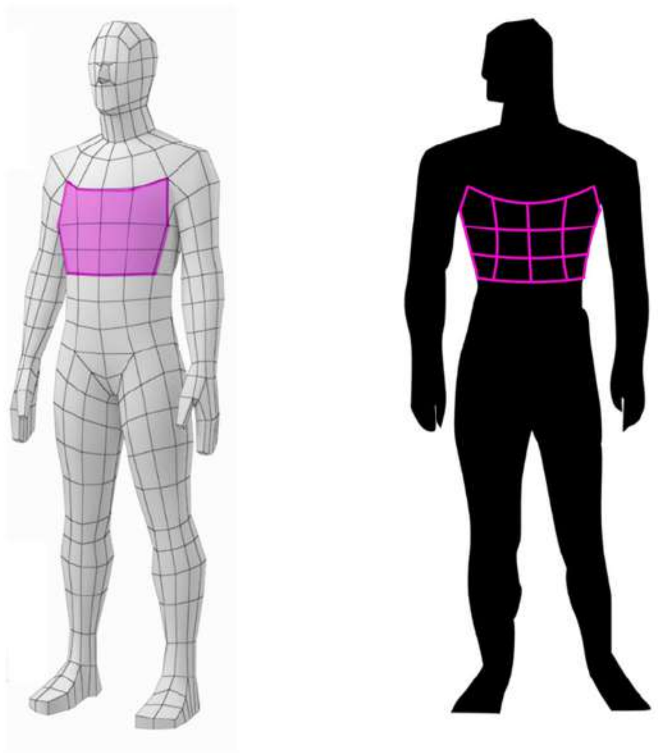
However, according to Mercè Ginjaume, the nuclear medicine law is quite reluctant to change. It takes a lot of time and money to include new updates. This constraint could affect us notably, introducing delays of years on the process of putting LUMO on the market and certifying the people involved in the process. Therefore, these options were discarded.

After some research, we found several companies like Codisa, in Esplugues de Llobregat (Barcelona), that generate and distribute radiomedicine to hospitals in a determined radius. As reported by Mercè Ginjaume, the properties of Technetium-99 (the radiopharmaceutical that could be used in our project) would allow it to be transported all around Spain. This option was the most viable, as these companies already have the proper infrastructure, licenses and certifications to manipulate radioactive material.

2.2 SCANNING

Our aim was to do a portable solution, easy to move around. The radiation level of the technetium-99m is 140 KeV, whereas Fluor18 (PET) is 511 KeV. As it is a low dose, the doctor is allowed to be in the same room as the patient while doing the scanning. To avoid and control radiation, the doctor must wear the appropriate protection (a dosimeter, a plumb apron) and follow the protocols in the normatives. However, the room must be shielded to provide protection from penetrating radiation, as X-Ray rooms.

Knowing this information, we could keep on the track of developing a device that could be manipulated by the doctor. We aimed to track the exact position of the device in the space. Being precise was important, as the error captured would affect the 3D reconstruction. Thus, we came up with the idea of using a grid to map each point of the digital body with the body of the patient. This grid could be “drawn” on the patient by sticking it like a temporal tattoo, or using special clothing with the lines painted on it. Nevertheless, this may cause inconveniences to some patients. Instead, we thought of making this grid “virtual” and working with the software and the device simultaneously.



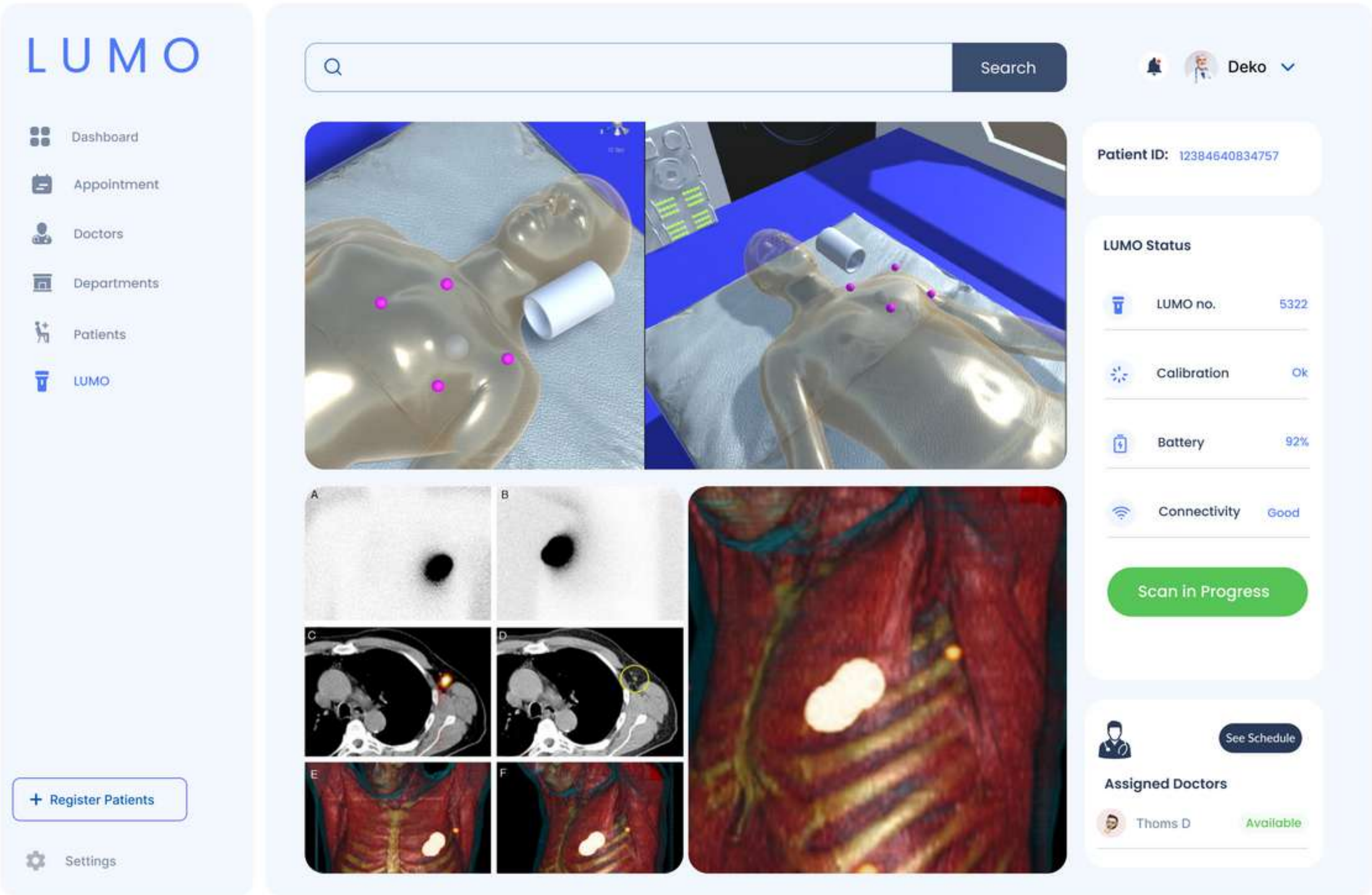
In the image shown above we can see an example of the digital mesh, and how it would correspond to the tattoo/special clothing of a real person. By making this grid virtual, we would substitute the mesh with a specific number of points located in a specific part of the body.

In order to improve the precision of the movement, we thought about moving the device with a robotic arm. This would help in keeping a better track of the position of the device. However, it would increase the cost notably, and the device would lose its portability, which was one of our objectives.

2.3 DISTRIBUTION OF RESULTS

After the interviews with Dr. Josep Munuera, we realized that if we wanted doctors to use our product, we had to ensure that they could obtain the information clearly and easily. Having this in mind, we came up with the idea of using virtual reality goggles. This would help the doctor seeing the tumor inside the patient's body in real time. However, we didn't think this was a comfortable way to share the results with other doctors or store the information. Besides, we aimed at displaying more relevant data at the same time that the reconstruction was going on and this wasn't really possible if all the visual field was destined to the reconstruction. In our opinion, these constraints could make the doctor decide not to use our product, so we decided to not consider them.

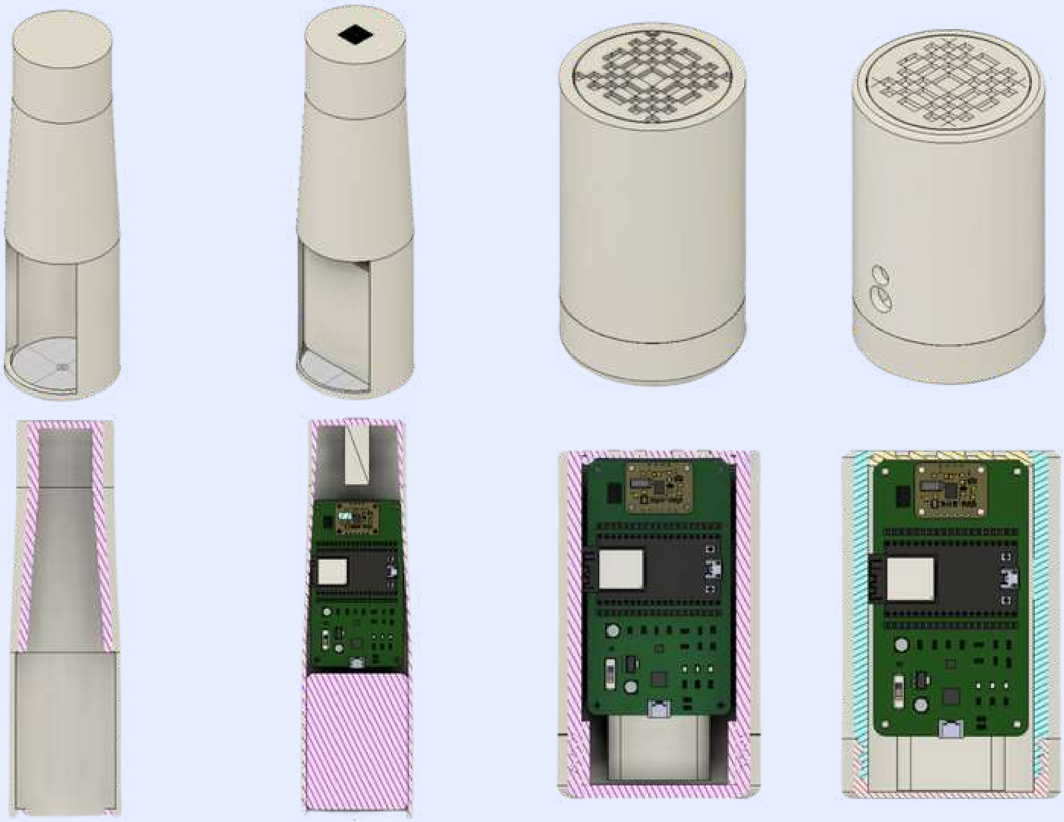
Instead, we preferred to link the device with a software that contained all the necessary information of the patient and made it easy to analyze the results, as will be shown in the section below.



2.4 PROTOTYPING

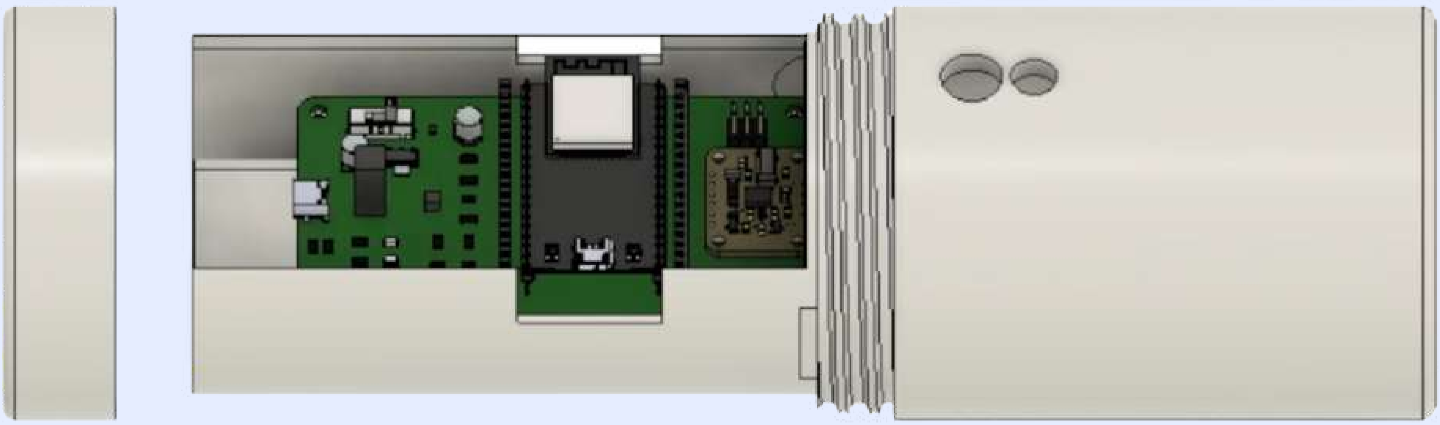
Once the idea was well defined, the prototyping phase began. On the one hand, we had to figure out how to develop the physical device. First, we started by talking about how we imagined LUMO. It was really important to make sure the device was light and easy to handle with one hand. In order to make sure of it, we made a rough cardboard prototype, just to figure out the approximate dimensions of the device and make sure the electronics fit inside. It consisted of a half-cylinder of cardboard inside another cardboard cylinder.

Putting one cylinder inside the other allowed the electronics to be hidden and protected, at the same time they were easily available if any change was needed. We decided for a rounded form, as it's more ergonomic. Knowing this, we started making different 3D designs, until we achieved one where the electronics fit and it's compact enough. The progress is shown on the image below, from left to right.
Then, after deciding the model, we wanted to test the thread. As we didn't have experience, we wanted to verify that the tricky parts of the 3D design were correct before printing the whole piece. Once the thread was printed, we had to readjust some measurements that weren't entirely correct so it worked properly. Then, after fixing this we printed the whole piece in white PLA.



Evolution of the design of the device

Printing was one of the first tasks in the prototyping phase, as it takes so many hours to print a piece of this size and. As we didn't want to be behindhand, we did this task simultaneously with the development of the software simulation and electronics. A custom PCB was made in order to reduce the amount of wiring and provide a "cleaner" prototype. By soldering all the components to the board, the result was very compact. The software helped us simulate POSICS. At the same time, it verified that the electronics part worked properly and computed the reconstruction of the tumor, as will be explained later on. The process of developing a software program was long, as we wanted to make it understandable and user friendly, but above all, functional.



3. FINAL IDEA & SOLUTION

After all the information search, filtering, analysis, and the process of validation and prototyping, we achieved a final idea that met the main objectives of the project.
We have implemented a portable device, which meets the technical requirements of scanning, position tracking, data transmission and 3D reconstruction of these data. At the same time, its use and management is highly intuitive and does not imply any extensive technological knowledge for its use.

With LUMO, we aim to provide second level hospitals the necessary tools to improve the accessibility to cancer checkups. We believe the design and functionalities of this product, which are explained below, are a big step forward to tackle this issue. Besides, by bringing the solution closer to the patient, the patient journey can be reduced from 45 to 14 days. Consequently, LUMO would help in reducing the stress and nerves of patients, ensuring their well-being.

Nowadays, nearly 900,000 people in Spain are undergoing the treatment of cancer and could benefit from our solution to do their checkups, reducing their uncertainty and time of travel.

Diagram of an average cancer follow-up journey

Diagram of a cancer follow-up journey using LUMO

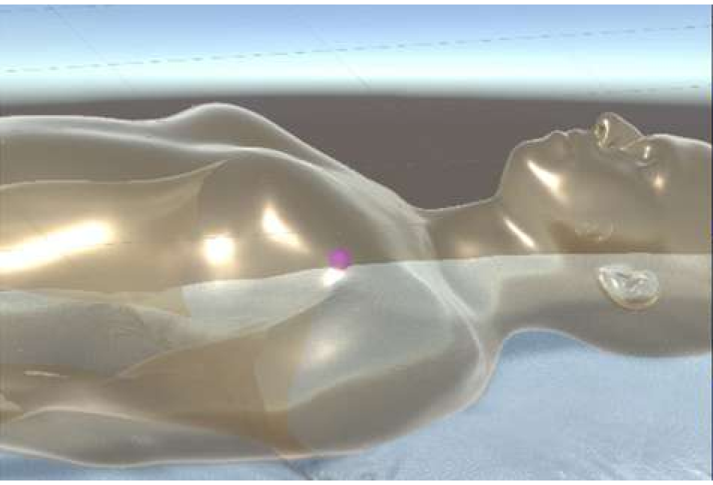
3.1 HOW IT WORKS

LUMO intends to be intuitive for the doctors. The steps to follow in order to achieve a good scanning and result are listed below:

- The device should be calibrated before starting to scan. The calibration process involves performing some rotations and movements, and it needs a flat surface where the device can rest still for a moment. The status light indicates successful calibration.
- Once the device is calibrated, next step is to acquire the reference position. This is necessary to align the data captured in space with the visual representation in the software. In the prototype, this is done by placing LUMO on the left shoulder of the patient, with the sensor pointing his/her feet and with the button facing the same direction of the patient's eyes. Then, the control button must be pressed until the device on the simulation is placed in the same position as the real device.

- To start scanning the patient, we must click the control button. Then, the simulation will indicate the new position and orientation of the device. Multiple images taken from different positions and orientations allows us to identify the position of the tumor in 3D. While scanning the area, the sensor detects samples of the gamma rays emitted by the tumorous cells. Once it considers that it has enough information of that position, the device will emit a sound signal so the doctor knows he can go to the next position.

- When samples have been taken from sufficient perspectives, the 3D reconstruction of the tumor will be carried out using all the data taken and signal processing algorithms that will draw the outline of the radiotracers' location. This will indicate where the patient's tumor is located, if there is one. With this prototype, a single radiotracer source is simulated.



3.2 TECHNICAL DETAILS: THE ELECTRONICS OF LUMO

- To be able to perform the scan, both LUMO and its visualization software running in a computer are needed. In the previous section, we explained how we used a simulation to prototype the visualization software and the reconstruction. In this section, we talk about LUMO as a physical device, able to perform scans and send the data to the computer, and the prototype that was built to validate the whole concept.

3.2.1 LUMO'S SUBSYSTEMS

In the following section, the main subsystems of LUMO are identified. Each subsystem has a description of the function it accomplishes in LUMO, and the specific part that was used in this first prototype.

- The POSICS-2 sensor, which is composed of a collimator, a scintillator and a SiPM that is able to take a 2D image sensitive to gamma (or beta) rays. This sensor is currently in development by the team of scientists at cern led by Domenico della Volpe.

- The Inertial Measurement Unit (IMU). This sensor is responsible for accurately measuring the orientation of the device. The heart of this component is a 9-axis IMU integrated circuit that combines an accelerometer, a magnetometer, and a gyroscope. The specific model used in the prototype also integrates a microcontroller that, in combination with sensor fusion algorithms, is capable of accurately measuring orientation in real time.

- The RF Module. This component enables the device to act as a WiFi hotspot, making the connection between LUMO and the PC straightforward. For this prototype, an ESP32 module has been used. This SoC has the advantage of providing a dual core microprocessor on top of the radio. This has allowed us to use this component as the brain of the prototype without needing another integrated circuit.

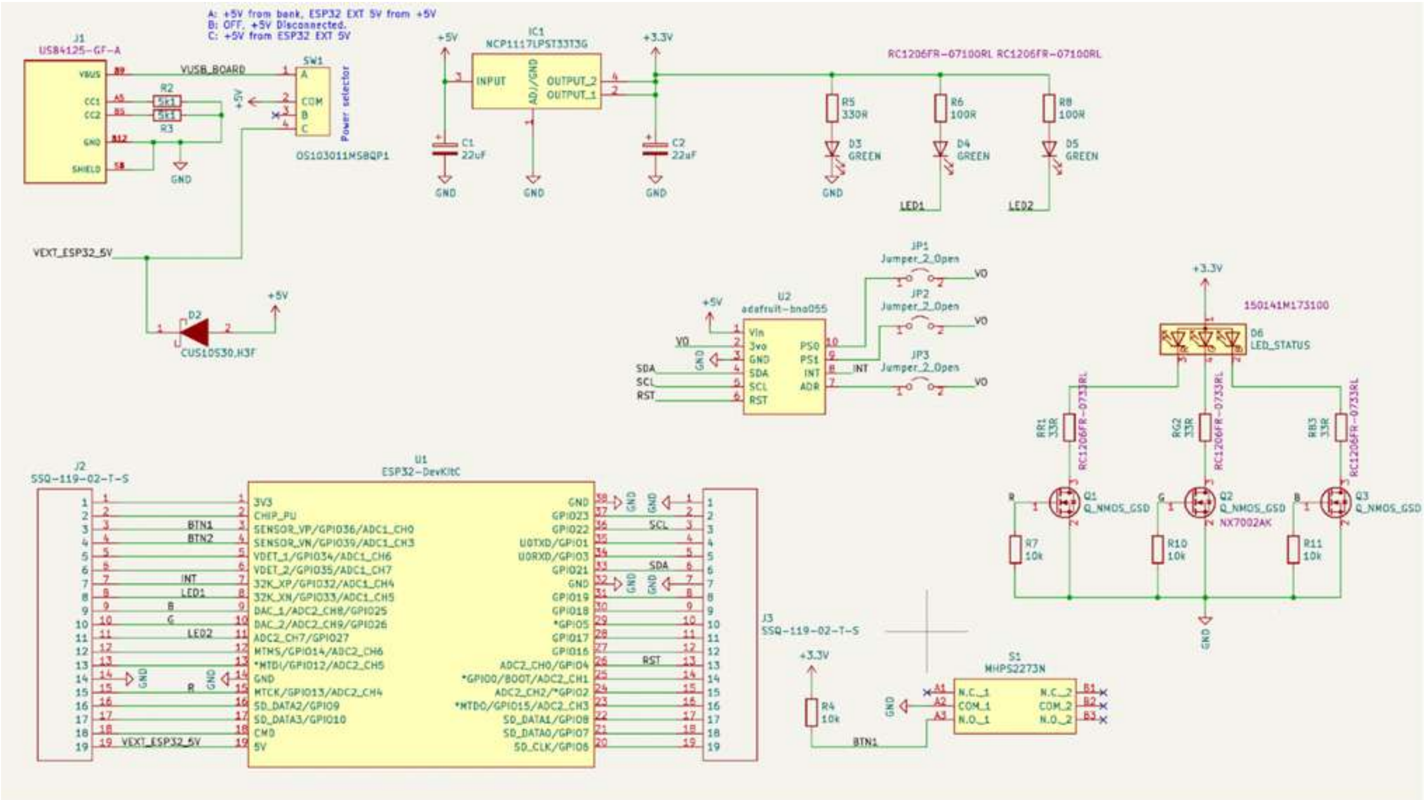
- The rechargeable battery. This is implemented as a portable power bank in the prototype, providing the charging, protection circuits and regulated output needed for our application.

- User interface. LUMO provides buttons and indicators to aid in the scanning process. A button and color LED has been included in the prototype.

3.2.2 LUMO'S ELECTRONIC PROTOTYPE

All these subsystems can be considered the main parts of LUMO. But to make LUMO work, these need to be integrated, both electrically and mechanically. And this was not different in the first prototype that we presented. In the next section, the process to realize the first prototype is explained.

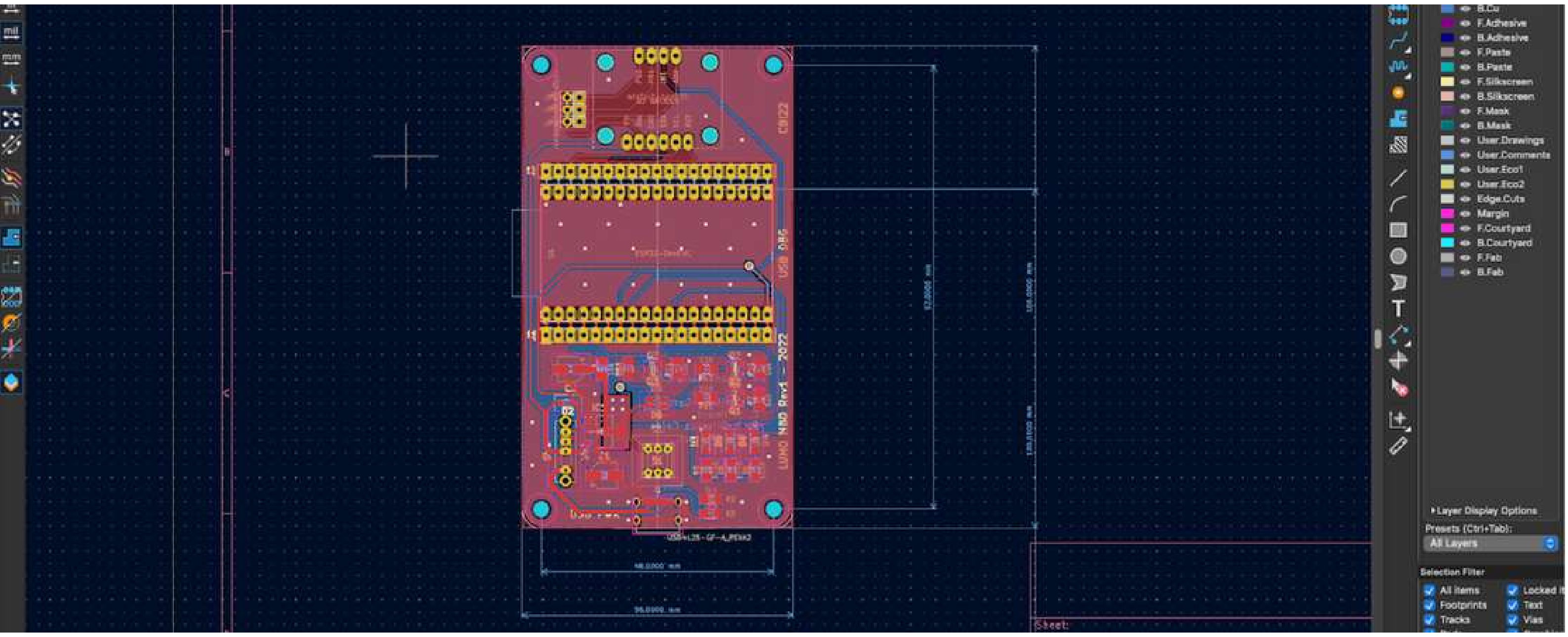
The process started by selecting the main components and capturing the design in electrical schematics.



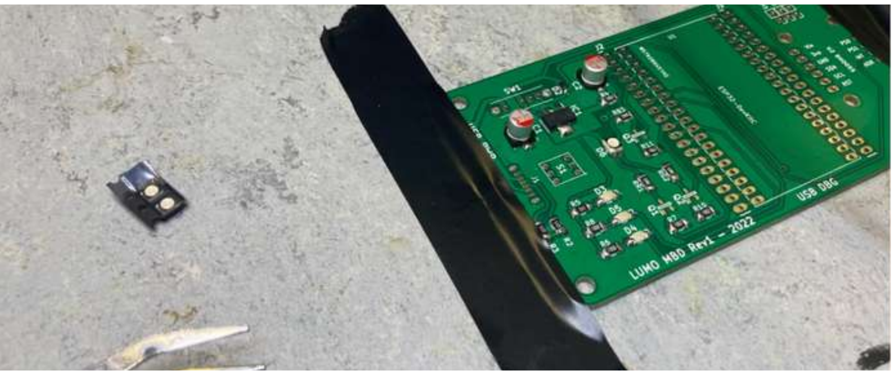
LUMO

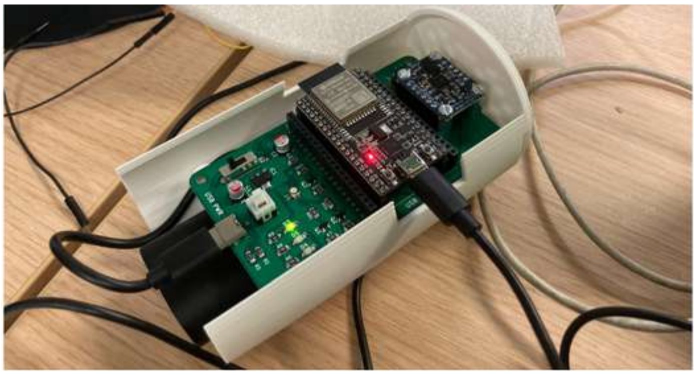
Once all the electronic components are selected and its values chosen, the next step was to design a custom printed circuit board to implement the design. This has to be done taking the mechanical design of LUMO into account. Even if the first prototype is 3D printed, some fixing elements were added to the design. In this case, electrical design, mechanical design, and component selection was an iterative process, as is the case in most designs.

When the electrical design was finalized and physical requirements set, a bill of materials was generated and all the needed components were ordered, and the printed circuit board design began.



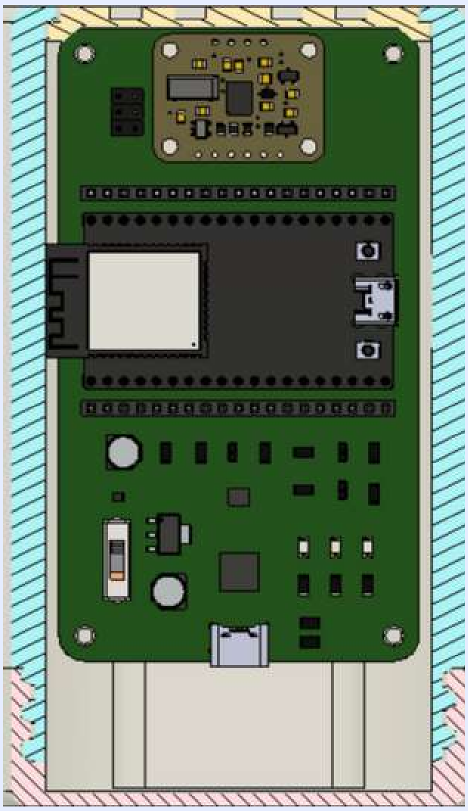
The printed circuit board was designed by using an open source CAD software named KiCad. Once the printed circuit board design was complete, fabrication files were sent to providers specialized in manufacturing prototype boards. The components were soldered onto the PCB. When the board was populated and the parts of the enclosure printed, the device was assembled. For the creation of the casing and the 3D prototype we have used the Fusion 360 program that has allowed us to generate the 3D model, but also the plans, disassembly video and a virtual visualization of it before taking it to print.





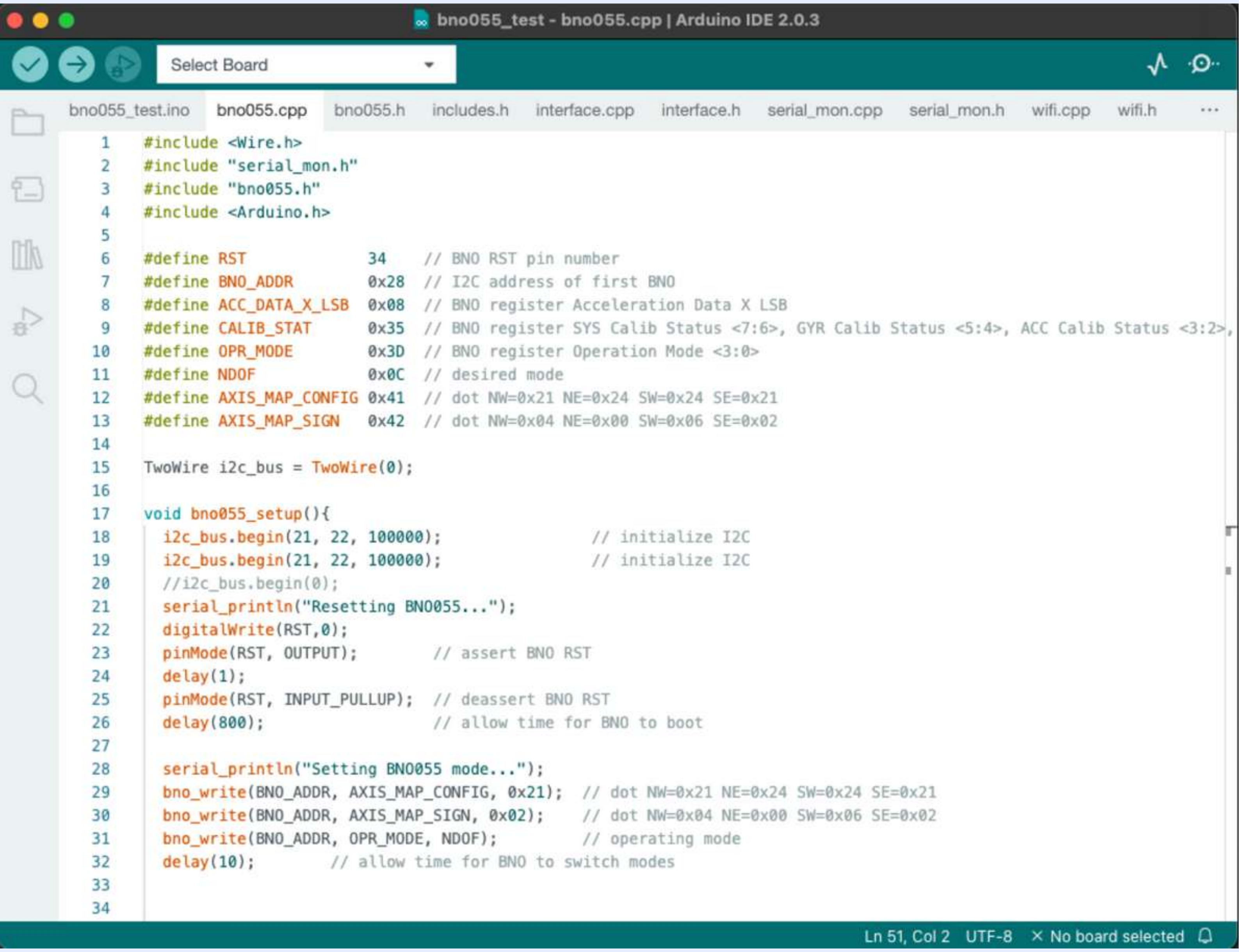
After several iterations it was concluded that this is the best version for several reasons:

- More comfortable to hold: because it is easy to grip with a hand size within the average, and possible leverage effects are avoided as in previous models.
- Comfortable opening system: this system is easy to model and esthetic. The fact of using a thread allows us to open the device and be able to manipulate it easily, and it does not affect the user experience at all.
- Holding of the elements: due to having the 3D model of our PCB we have been able to adjust everything to make it as compact and firm as possible so that everything fits without any complications.
- Control by the user: The added control button is comfortable and useful, and this avoids having to use external elements (keyboards, mouse) to control the system.



3.2.3 LUMO PROTOTYPE FIRMWARE

For the prototype to work, it needs to run a software that commands the sensors, RF module, and handles the inputs from the user. This software was developed in Arduino, an open source platform specifically aimed at prototyping. The code is written in C++, and uses Espressif's ESP-IDF arduino package.




```
#include <Wire.h>
#include "serial_mon.h"
#include "bno055.h"
#include <Arduino.h>

#define RST             34    // BNO RST pin number
#define BNO_ADDR        0x28  // I2C address of first BNO
#define ACC_DATA_X_LSB  0x08  // BNO register Acceleration Data X LSB
#define CALIB_STAT      0x35  // BNO register SYS Calib Status <7:6>, GYR Calib Status <5:4>, ACC Calib Status <3:2>,
#define OPR_MODE        0x3D  // BNO register Operation Mode <3:0>
#define NDOF            0x0C  // desired mode
#define AXIS_MAP_CONFIG 0x41  // dot NW=0x21 NE=0x24 SW=0x24 SE=0x21
#define AXIS_MAP_SIGN   0x42  // dot NW=0x04 NE=0x00 SW=0x06 SE=0x02

TwoWire i2c_bus = TwoWire(0);

void bno055_setup(){
  i2c_bus.begin(21, 22, 100000);              // initialize I2C
  i2c_bus.begin(21, 22, 100000);              // initialize I2C
  //i2c_bus.begin(0);
  serial_println("Resetting BNO055...");
  digitalWrite(RST,0);
  pinMode(RST, OUTPUT);         // assert BNO RST
  delay(1);
  pinMode(RST, INPUT_PULLUP);   // deassert BNO RST
  delay(800);                   // allow time for BNO to boot

  serial_println("Setting BNO055 mode...");
  bno_write(BNO_ADDR, AXIS_MAP_CONFIG, 0x21);  // dot NW=0x21 NE=0x24 SW=0x24 SE=0x21
  bno_write(BNO_ADDR, AXIS_MAP_SIGN, 0x02);    // dot NW=0x04 NE=0x00 SW=0x06 SE=0x02
  bno_write(BNO_ADDR, OPR_MODE, NDOF);         // operating mode
  delay(10);         // allow time for BNO to switch modes


```

4. IMPACT

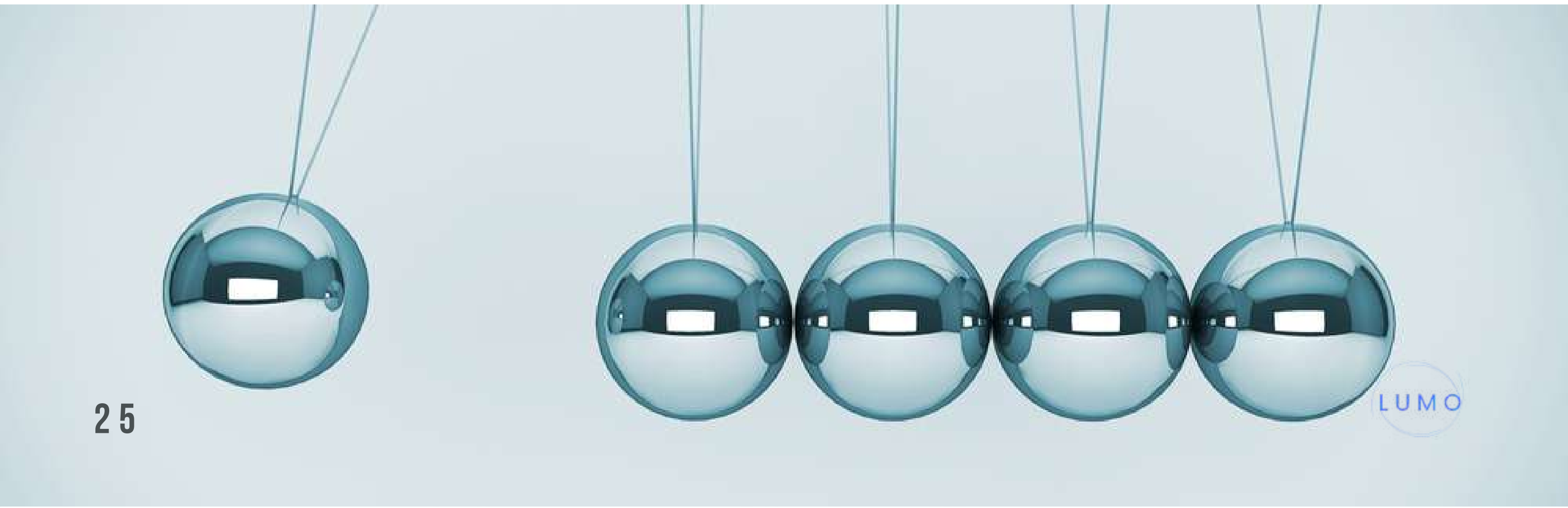
We envisioned this solution to have high potential impact in the medium/long term horizon. That is, this solution would have to first undergo clinical trials before full implementation. In order to have a more accurate assessment on this impact, we had to look internally first, before looking at the key stakeholders in this entire process.

We started our impact assessment by looking into how we would structure a solution. We considered different options that we can ensemble an organization that would be accountable for pushing the solution and keep maintaining it and growing it. We decided that a social purpose enterprise, where definitions of our objectives, mission, and values are clear. Doing so will enable us to attract the right funding and right people that would help the solution grow, while maintaining the for-profit aspect of an enterprise will ensure self-sustainability.

Purpose:
Support cancer patients in their treatment journey.

Mission:
When it comes to inequality, access to healthcare inequality is overlooked. We aim to fix this inequality by empowering small local hospitals with capabilities to support more cancer patients throughout their treatment while maintaining the patients' quality of life.

Values:
- Agility: We need to move fast and be flexible to improve healthcare accessibility
- Care: Patients wellbeing is our number one priority
- Compassion: We listen from all stakeholders in healthcare to develop compatible solutions
- Cooperation: We believe in the importance of partnership to solve healthcare issues
- Innovation: We push ourselves to rethink existing systems to solve problems from the roots



LUMO

We also looked into how we would want to structure this enterprise. The following are the main work streams that we envisioned for the next five years.

- Operation (COO) – Include two streams of developing and provide support to future clients for the physical device, as well as software development and technical support for the accompanying software.
- Sales & Marketing (CMO) – This stream is focused on branding, website maintenance and raising awareness for the device. In the future, this would also include sales force and clients’ relations.
- Backoffice (CFO) – This should include finance, accounting, controls, HR and other administrative tasks.

4.1. COSTING

It was essential to track all costs for this solution in order to assess how this solution would compare to other existing solutions. By building our own prototype, we were able to estimate the costs of the material to $5,000. This cost is less than 1% the price of an average PET scanner, which makes the device more appealing for smaller hospitals and medical facilities. We estimated more costs for shipping and assembling the product at a margin of %50, bringing the entire direct costs to $7,500. We also looked into the costs of developing the software. Considering a hosting service, cybersecurity, in addition to software design and construction, we estimate these costs to be at $100,000. There are other accompanying costs, such as branding and other costs that we discuss in more details in later sections.

4.2. CLINICAL TRIALS AND EUROPEAN CERTIFICATION

The first step for any medical device to be available to use, it needs to get certified and undergo clinical trials. This process could take up to three years, as we learned from discussing with the different Attract researchers. We identified two potential hospitals, Hospital Universitario La Paz and Vall d'Hebron, to approach for these trials. We chose those two because they have the required access to facilities and radiotracers to conduct a clinical trial and compare results. They are also both large enough to have more patients, which can add more dimension to make the process holistic and help completing the number required for trials.

We estimate that the costs would be $650,000 for the duration of this stage. These costs extend beyond the development of the product and software. We expect to incur costs of analyzing data received during the clinical trials. We also consider the setup fees for the enterprise and other legal fees for obtaining the certification from the EU. Finally, once the clinical trial succeeds, we aim to allocate a substantial budget to campaign and raise awareness on this solution so more regional hospitals are aware of this alternative.

4.3. OPERATIONS & SHORT-TERM IMPACT

Following obtaining the certification, we plan to ramp up the marketing efforts and recruit more sales forces to help with growth. We will aim to implement the solution at 50 local small medical facilities in Spain. We also expect a need for more software engineers to provide customer support in cases required.

At the scale which we are aiming for, we are expecting many fixed costs to reduce, especially software costs. Therefore, we expect to be able to sell at $30,000 and still make a significant margin to help further expand the reach of the solution. At this price, Lumo as a solution is significantly cheaper than PET scanners and CT scanners. Moreover, the radiotracer Lumo uses (Tc-99) is cheaper by half, when we compared price quotations online, than the common radiotracer (FDG-18) that most PET scanners require. In addition to the radiotracer, Lumo requires minimal operational costs, such as electricity to charge the device and fractional hours for medical professional time. When we compare the operational costs of a PET scan facility which can reach up to $400,000 annually.

Our strategy for the initial expansion is to approach hospitals who are located close to a radiotracer manufacturing facility. We identified multiple facilities around Spain, and they seem to be more concentrated in Madrid, Basque Country, and Catalunya regions. The distance is important as the half life of the radiotracer cis about 6 hours, which means it needs to be injected to the patient's body within that time frame.

Another important aspect in our strategy is marketing and campaigning to raise awareness on the device so more doctors, even patients too, are aware of it and interested in using it. This would include participating in medicine and tech-conferences. We also want to consider inbound marketing, to avail more resources online, and offline, for people impacted by cancer, whether that was a doctor, a patient, or a family or friend of a patient. We want to orient the solution as an alternative, and not a substitute, to PET scans. Doing so will enable more access to more medical tools and alleviate some pressure from radiology departments at large hospitals in Spain.

To solve such a complicated issue pertaining healthcare inequality, cooperation of many stakeholders must take place. We identified cyclotron facilities, local hospitals, and medical professionals as the most important key partners. Once the solution gains momentum, we would expect to have more locations producing these radiotracers after 5 years. By looking at current trajectories of growth, it is estimated that radiology is expanding by 37% in the same timeframe. At the same time, we need to encourage research on the same technology to reduce and potentially eliminate the need for using a radiotracer component.

4.4. SOURCES OF FUNDING

To accomplish this desired impact we aim for, we also explored potential sources of funding. We shortlisted 4 venture capitals that can add value to us and potentially be interested in our solution.

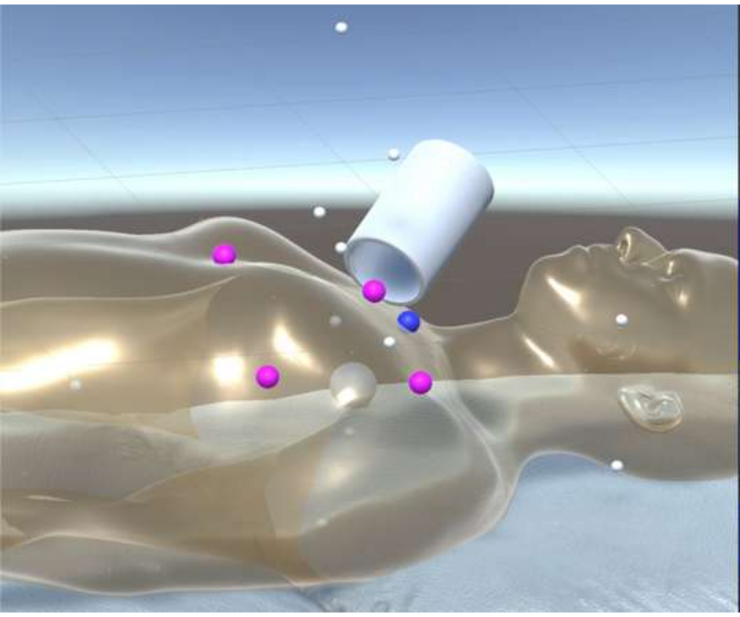
- Nina. Capital – Oncology startup experience and EU focused.
- ASABYS – Catalunya based and very active in oncology startups.
- Caixa – Ticket size is relevant to our requirements and active in health tech.
- Novartis – Radioactivity experience that we can gain from at the radiotracers front.

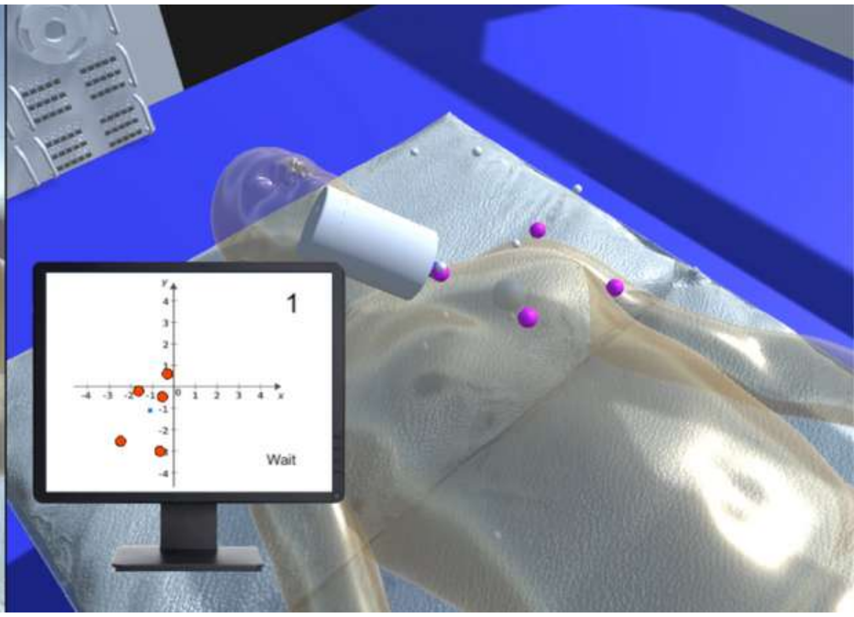
ANNEX I: 3D RECONSTRUCTION

The reconstruction has been created with Unity, which is a graphic engine that allows the creation of 3D games and simulations in a simple way and. It has been chosen due to the mastery of previous knowledge that we have about this programs.

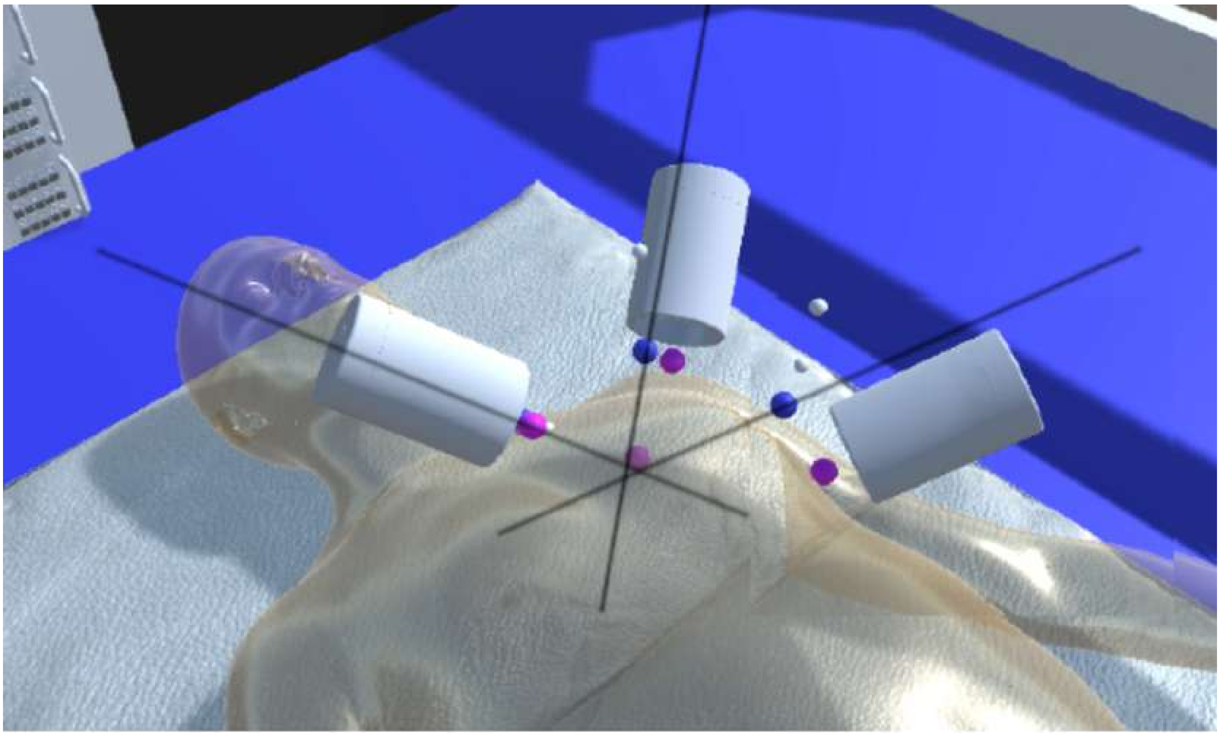
The reconstruction is formed by several different objects that carry out the functionalities detailed below:

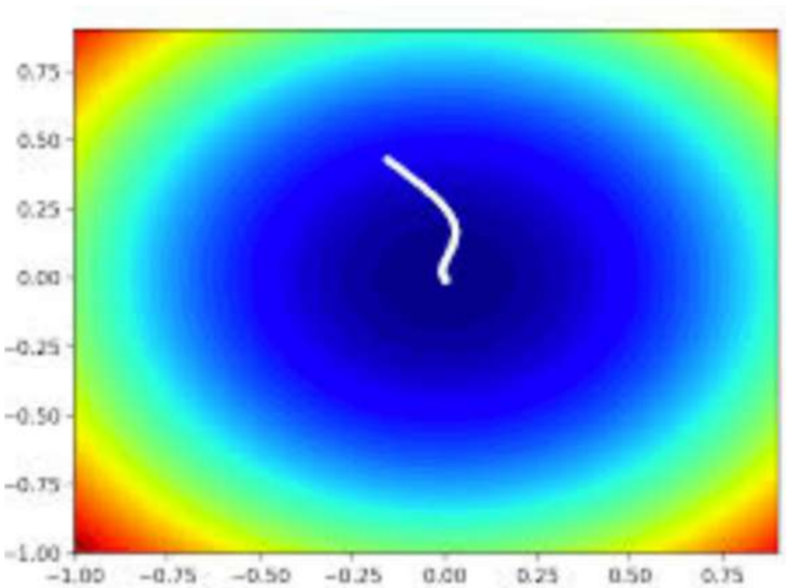
- Tumor: It is represented as a big white ball. Each frame, the tumor points to a random direction and emits a new particle in that direction, which represents the gamma radiation emitted by the tumor. To avoid saturating the simulation, this “particle of radiation” will disappear after 5 seconds unless it hits the LUMO device.
- LUMO: The device is depicted using a rendering of the 3D printed model, and it has several functions:
    - Data reception: Using data reception control libraries and the TCP/IP protocol over the WiFi network, the software receives data indicating the rotation of the object in real-time using the Quaternion format. This rotation is then applied to the 3D model. The software receives information about changes in position in order to move around the body.
    - Collision detection: Using internal Unity colliders, if a particle emitted by the tumor hits the detector, the impact position is recorded in a list of 3D positions. When six samples are collected, a line perpendicular to the plane of the sensor that passes through the midpoint of the collisions is calculated and saved in a vector of lines. To simulate reality, if a particle arrives at an angle greater than 30° relative to the perpendicular to the plane, it is discarded, as this is how the collimator would work in reality.





- Tumor indicator: After all lines have been calculated, the intersection of these lines should coincide with the position of the tumor if they were perfect. However, due to randomness, this will not always be the case. To find the position of the tumor, we must find the point that is the minimum distance from all lines. To do this, we will use a gradient descent algorithm that minimizes the total distance. This process involves starting with an initial position for the point and calculating the distance to all the lines. If we move the point slightly and recalculate the distance, and it increases, we will move in the opposite direction and continue this process until we find the minimum distance.





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