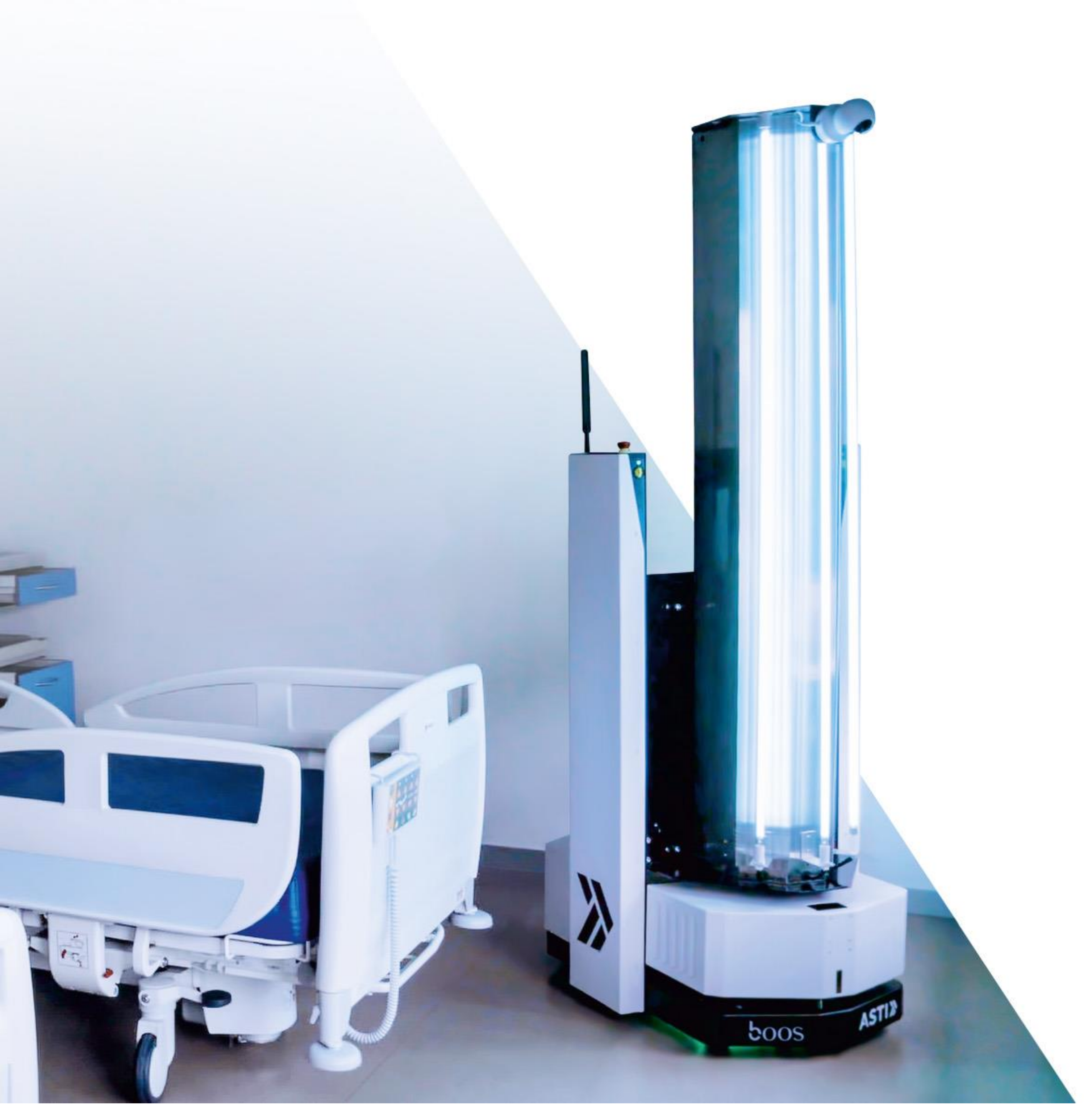
boos
Technical Lighting S.L.

ASTI
MOBILE
ROBOTICS

DISINFECTION
SOLUTIONS

ZenZoe



History

Rev.	Date	Author	Description
V.01	12-05-2020	FRM	Initial report
v.02	21-05-2020	FRM	Short result table

TRACEABILITY REPORT OF THE MITIGATION OF COVID-19 WITH THE PILOT TEST OF "ZENZOE ROBOT" AT THE UNIVERSITY HOSPITAL OF BURGOS

Hospital Universitario de Burgos

ON APRIL 27 th AND 28th 2020

1 INTRODUCTION

1.1 INFORMATION ABOUT THE TWO COMPANIES THAT CONDUCTED THE PILOT TESTING

1.1.1 ASTI Mobile Robotics Group

Asti Mobile Robotics Group, *transforming the future together*, is an international group of mobile robotics companies. An engineering company dedicated to the study, design, manufacture, commissioning and maintenance of internal logistics automation solutions, that is, the movement of materials and products within companies, using automatic guided vehicles, called AGVs (Automated Guided Vehicles).

With the widest range on the products and market for driverless vehicles, ASTI Mobile Robotics Group is the leader in Europe, for the fourth consecutive year in its sector in the manufacture of mobile robots. The ASTI Engineering Dpt. is an expert in industrial connectivity and in data analysis provided by mobile robots. In 2019 ASTI Mobile Robotics Group integrated InSystems Automation in Germany as part of the group. Currently, the company has offices in Burgos and Madrid (Spain), in Mulhouse (France), in Berlin (Germany) and in North Carolina (United States).

1.1.2 BOOS Technical Lighting S.L.

BOOS Technical Lighting SL. belongs to the ILEC Group (International Lighting Engineering Company) which has more than 30 years of experience in the design, manufacture and marketing of luminaires, as well as management, control and monitoring systems for intelligent lighting solutions.

Flexible, interconnected, configurable products and systems that ensure the best ratio “irradiation generated by consumed energy” in the sector of lighting, increasing the efficiency and effectiveness in germicidal emission and ensuring the most adequate dose to obtain the inactivation of the highest logarithmic index of pathogens.

Wide range of optical systems that maximize the performance, in vertical, semi-cylindrical and horizontal planes, of all lamps and light emission sources, including LEDs, along the visible and ultraviolet electromagnetic spectrum. Extensive knowledge in the sectors of outdoor, indoor, horticulture and germicidal ultraviolet lighting.

1.2 EFFICIENCY OF ULTRAVIOLET LIGHT TO DISINFECT COVID-19

The main objective of sterilization is the destruction or the inactivation of any type of microbial life. An example of a sterilization process would be applied in surgical instruments. Disinfection, on the other hand, is a process during which much of the microbial life is destroyed or with which attempts are made to inhibit the harmful effects of microbes in humans. Disinfection, for example, occurs when we clean a room or toilet.

Ultraviolet (UV) light is a form of light invisible to the human eye. It occupies the portion of the electromagnetic spectrum located between X-rays and visible light. The sun emits ultraviolet light; however, the terrestrial ozone layer absorbs much of it. A unique characteristic of UV light is that a specific range of its wavelengths, between 200 and 300 nanometers, is classified as a germicide, that is, it can inactivate microorganisms such as bacteria, viruses and protozoa. This ability has allowed the widespread adoption of UV light as an environmentally friendly way, without chemicals and very effective in disinfecting and protecting water against harmful microorganisms.

ZenZoe robot with UV light works as a disinfection. Unlike chemical based disinfection methods, UV radiation provides rapid and efficient inactivation of microorganisms through a physical process. When bacteria, viruses, and protozoa are exposed to the germicidal wavelengths of UV light, they become unable to reproduce and to infect. UV light has been shown to be effective against pathogenic microorganisms such as cholera, polio, typhoid, hepatitis, and other bacterial, viral, and parasitic diseases.

The effect is based on causing damage to the genetic material of the pathogens. The DNA, RNA and proteins of the microorganisms absorb ultraviolet light, producing a photochemical reaction that breaks the bonds of the genetic structure of the pathogen, thus inactivating the virus, bacteria or fungus.

One of the great advantages of this technology is that it is non-toxic, so once the cycle has finished, the disinfected area can be accessed without any waiting time. Likewise, the disinfection capacity of ultraviolet light on different types of pathogens is well documented in the scientific literature.

1.3 VALIDATION AND PILOT TESTING

This product has been verified in the NBC laboratory of the INTA (National Institute of Aerospace Technology) in collaboration with the UME (Military Emergency Unit) after having undergone tests that found out the reduction of the viral load on different surfaces.

The pilot described here constitutes the first pilot test in a Burgos Hospital (HUBU) and the second carried out in a real environment, after the tests carried out at INTA. After several conversations with the Preventive Medicine Department of the Burgos Hospital (HUBU), it was considered appropriate to raise the pilot testing on two successive days.

- On the first day, a plant with hospital rooms and other hospital facilities were disinfected with our ZenZoe robot
- On the second day, the work started the previous day was continued and the ICUs Intensive Care Units and Post Anesthetic Resuscitation Units , which had housed Covid-19 patients.
- Later, on the second day, the final pilot testing was conducted (explained in section 4 and 5 below)

1.4 MATERIAL USED AND PROCEDURE

The ZenZoe robot on which the prototype is based is an autonomous navigation vehicle developed by the ASTI Mobile Robotics, Berlin that is specially adapted to move autonomously through interior spaces such as corridors or rooms. It is equipped with the most advanced type of laser free navigation system: Simultaneous Localization and Mapping (SLAM).

The lighting system is a set of 3 low pressure mercury lamps placed vertically on a circular line (with an angle between them). Each lamp has an aluminum reflector that allows the light to be focussed towards the points of the installations and to improve the disinfection efficiency. The lamps have a spectral emission with lines in the ultraviolet C (254 nm) – B (310 nm) – A (350 and 390 nm), as well as in the visible range: 415 nm, 515 nm and 545 nm. See Figure 1.

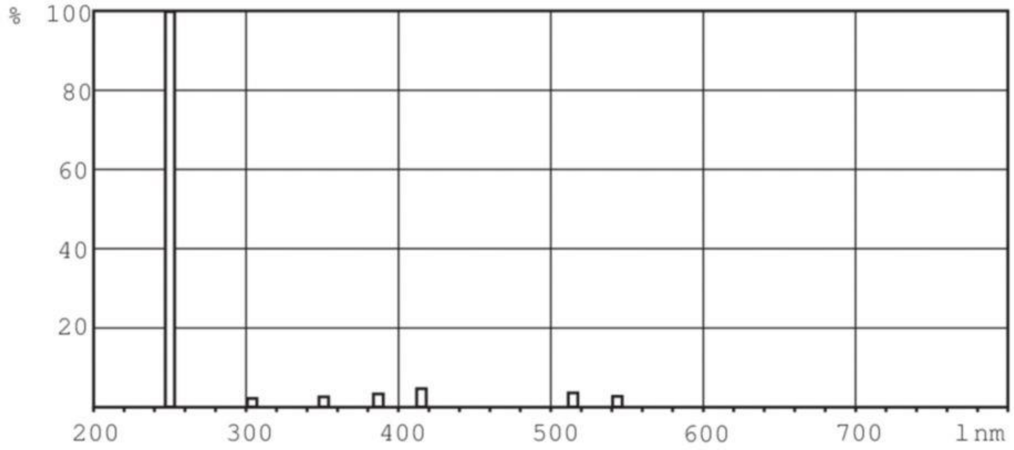


Figure 1. Emission spectrum of the lamp used in the disinfection process.

This solution is also based on advanced software developments.

On the one hand, the system has modeled the behavior of the ultraviolet lamp C and controls the levels of radiation x, y, z throughout the environment. With the clinical tests that are carried out for each type of virus or bacteria, the necessary radiation levels are established in mJ / cm2 to disinfect 99,99%, giving the distance to the surfaces, the speed of the robot, the number of passes for the most common pathogens.

On the other hand, the system registers in a black box all the movements and data obtained. In addition there is an entry application to record datas as responsible person of the treatment, room number and type of disinfection performed.

Likewise, although it has still been used in this pilot, ultraviolet radiation cores will be incorporated into the commercial product at different points in the rooms or radiation sensors that collect the data, will give the client the certainty that the system has projected ultraviolet radiation and therefore irradiation of pathogens has occurred.

This provides a total assurance that the disinfection process is carried out correctly because, being a robot, it will always pass through the same place at the appropriate speed and with the necessary radiation. As it is an automated process, it is less dependent on people and a greater capacity of disinfected m^2 per day is obtained.

As the robot moves, it can reach every corner of the room and disinfect up to 99,99%. The automatic version can also be operated by remote command and automatically recharges the battery when necessary.

Continuous movement prevents the appearance of shadows, even at the microscopic level. For example, behind a speck of dust there may be around 1,000 viral units. Therefore, if fixed systems are used, it may be the case that these viruses are not irradiated.

On the other hand, it offers the possibility of approaching horizontal surfaces (tables, bookcase shelves, etc.) which, added to the geometry of our lamps, allows effective light to be projected and thus reaching the appropriate doses.

2 SIMULATIONS CARRIED OUT

In order to guarantee the correct disinfection of the assigned areas, a study based on simulations has been carried out. This study is based on:

• Analyze the plans of the hospital facilities where you want to carry out the pilot.
• Identify repetitive patterns in assigned areas. Two-bed room, ICU area.
• Identify important points in the areas to be disinfected.

   o Double room: horizontal surface of the bed, horizontal surface of the bedside table, walls, headboard connection area.

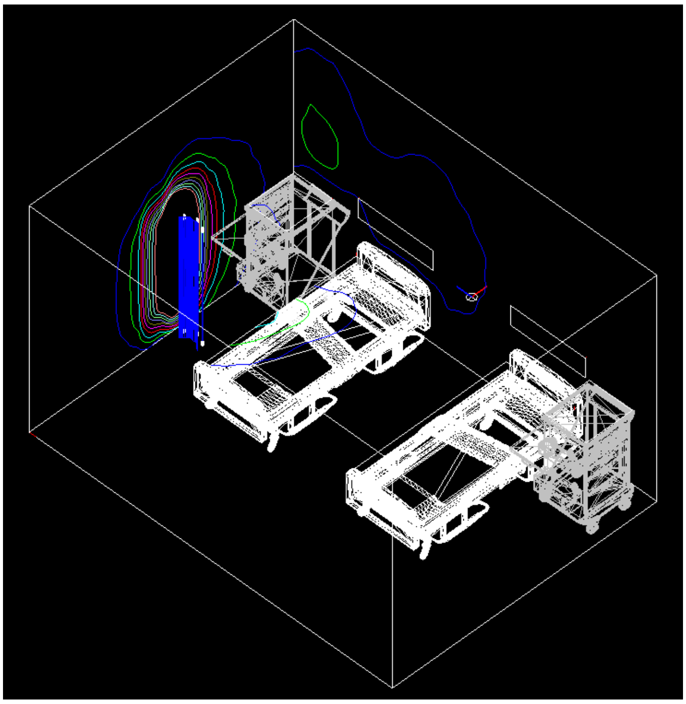


Figure 2. Example of one of the radiation points in the robot's path inside a standard two-bed room. Radiation level curves can be seen

- ICU area: horizontal surface of the beds, upper equipment connection head, side towers with electronic equipment.

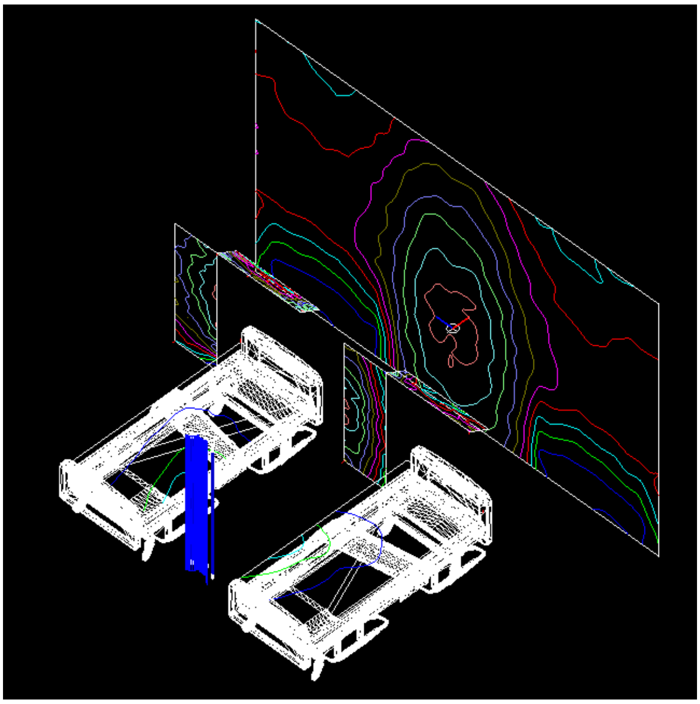


Figure 3. Example of the ICU study area. The radiation level curves can be seen at a specific point on the robot's motion trace during the demo

The simulation process is carried out using a ray tracer. The calculation device performs millions of processes, in such a way that it allows us to have a precise estimation of the radiation values at the different points in the sample area.

3 ROBOT PATHS

Once the work areas were fixed, these areas were mapped in such a way that the robot could carry out the disinfection process autonomously.

3.1 Double rooms

In the case of double bed room, we proceeded to make a path in which we entered the room and advanced to the windows, a bed was bypassed to reach the bedside table. At that point a 180 degree turn was made to go down to the other bed. The Robot approached the bedside table, turned 180 again and left the area passing between the two beds. Once this part was finished, the cabinets were irradiated from the inside and entered into the bathroom. At this point two complete turns were made to completely sanitize this area. Each of the rooms was visited twice by the robot. Each round of the robot is made with 4 minutes of time.

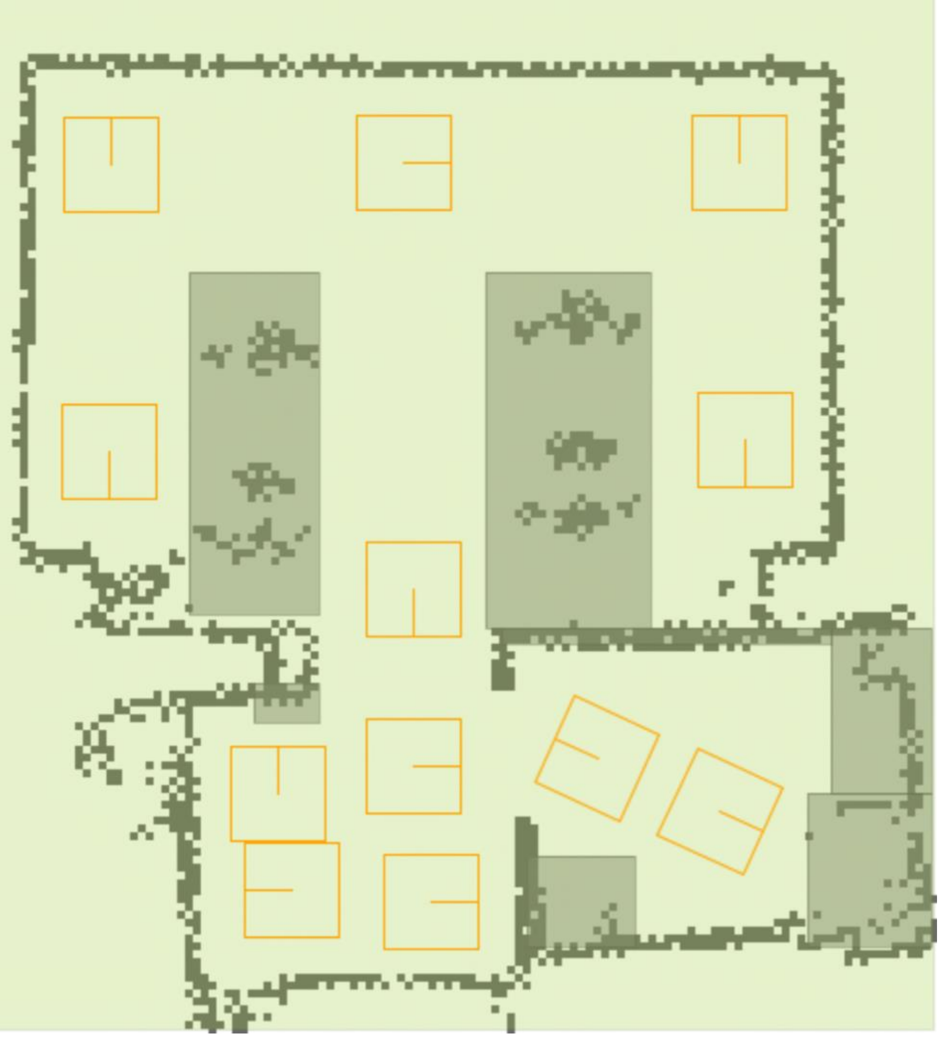


Figure 4. Schematic diagram of the robot path within the room obtained through the robot's own sensors. The walls of the room, the beds and the points where the robot made the different turns are perfectly observed.

3.2 Intensive Care Unit Areas.

In the case of the ICU areas, it was observed that it was divided into repetitive cubicles. The navigation of the robot consisted in advancing through the corridors between the beds in such a way that it approached the headboards where the different medical and informatic systems are connected. The necessary time to cover the whole surface of the tested ICU area was 30 minutes including 4 complete passes.

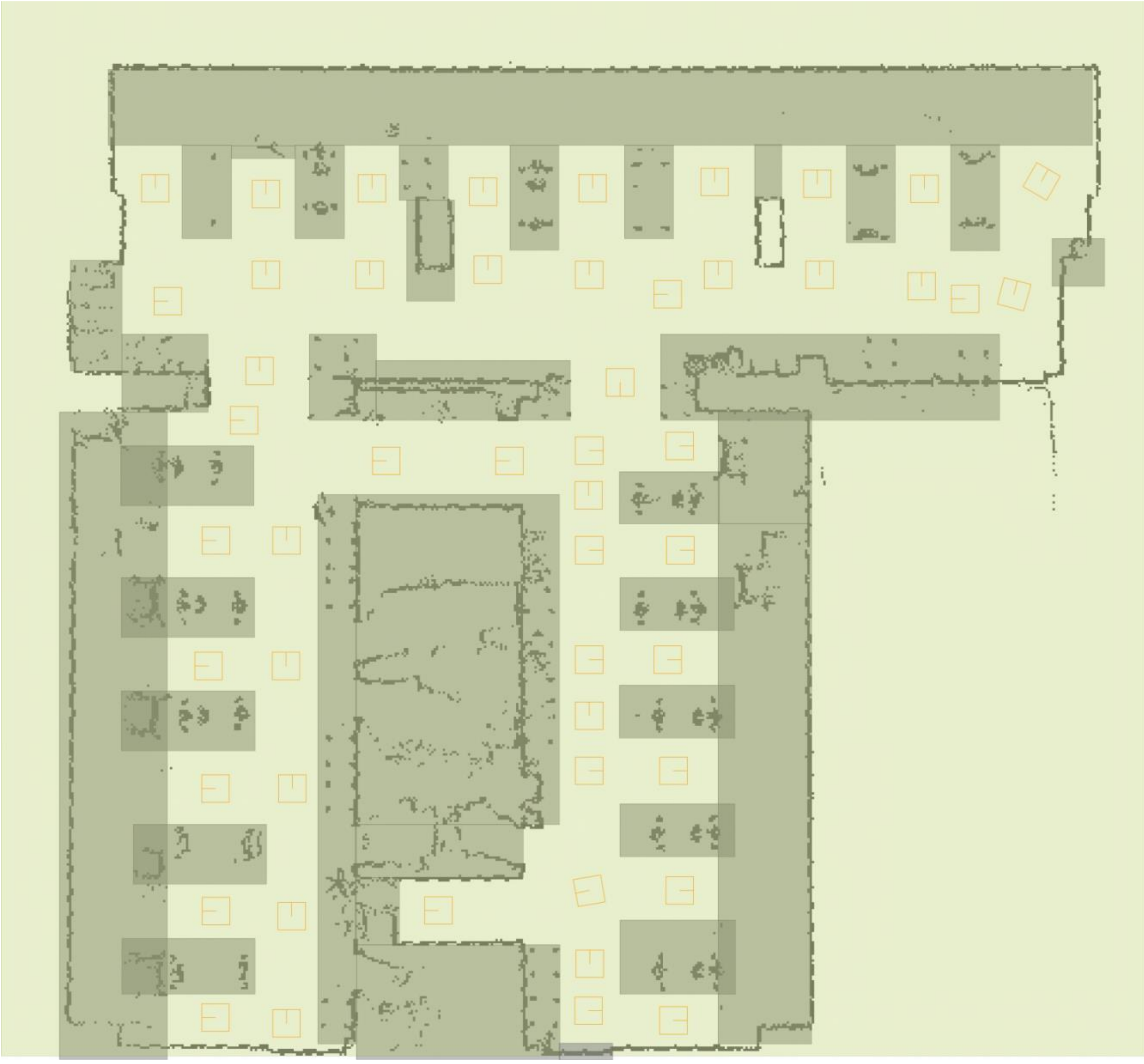


Figure 5. Robot mapping showing the beds and the points on the layout where the robot made the different turns to enter and exit the corridors.

4 RESULTS OF THE SIMULATIONS

The boundary conditions that were set both in the simulations and in the disinfection process were:

- Linear speed : 100 mm/s
- Turning speed : 10º/s
- Distance to surfaces, walls or objects : 500 mm maximum

4.1 Double rooms (2 passes)

Study area	Average level (mJ / cm2)
Wall 1	134
Wall 2	108
Wall 3	94
Wall 4	108
Bed 1	46
Bed 2	52
Table 1	30
Table2	**28**

4.2 ICU area (4 passes)

Study area	Average level (mJ/cm^2)
Wall 1	**96**
Bed	112
Instrument headboard	160
Instrument tower	520

5 DISINFECTION LEVEL

5.1 Double room

Based on the average levels reached in the different control zones, the minimum average dose reached is 28 mJ / cm^2. According to this value, the minimum desinfection levels are marked GREEN in the attached Table 1.

Table 1. Bibliography resume with representatitives virus, baterium and spores. In this table the UV-C susceptibility level of the different pathogens is show. With the avarege value of 23 mJ/cm² that is obtaiened in the worse case inside the room more of the pathogen had been desactivaten.

				Fluence for a given log reduction without photoreactivation (mJ/cm^2)					
Type	***Name***	***Code***		*1 D90*	*2 D99*	*3 D99.9*	*4 D99.99*	*5*	***Reference***
Spore	Bacillus atrophaeus	ATCC 9372		10	16	26	39		Sholtes et al. 2016
Bacterium	Aeromonas salmonicida	AL 2017		1.5	2.7	3.1	5.9		Litved & Landfald 1996
	Brucella melitensis	ATCC 23456		2.8	5.3	7.8	10.3		Rose & C'Connell 2009
	Escherichia coli	ATCC 11229		3.5	4.7	5.5	6.5	7.5	Sommer et al . 2000
	Legionella pneumophila	Sero group 8		1.8	3.3	4.7	6.1		Cervero-Arago et al. 2014
	Pseudomonas aeruginosa	NCTC 10662		1.5	2.6	3.8	5	6.2	Blatchley et al. 2016
	Staphylococcus aureus	ATCC BAA-1556 (Methicillin resistant)		4.5	7.2	8.8	10		McKinney & Pruden 2012
Virus	Coronavirus	SARS Hanoi		13.4					Kariwa 2004
	Coronavirus	SARS Urbani		24.1					Darnell 2004
	Hepatitis	A HM 175	FRhK-4 cell	5.4	15	25	35		Wilson et al. 1992
	MS2 coliphage	ATCC 15977-B1	E coli Hfr K12 ATCC 23631	6	23	21	29	37	Song et al. 2015
	Rotavirus	SA-11	MA 104 cell line	7	15	23			Battigeli et al. 1993

5.2 ICU Area

Based on the average levels reached in the different control zones, the minimum average dose reached is 96 mJ / cm^2. According to this value, the minimum desinfection levels are marked GREEN in the attached Table 2.

Table 2. Bibliography resume with representatitives virus, baterium and spores. In this table the UV-C susceptibility level of the different pathogens is show. With the avarege value of 96 mJ/cm^2 that is obtaiened in the worse case inside the room more of the pathogen had been desactivaten.

				Fluence for a given log reduction without photoreactivation (mJ/cm^2)					
Type	***Name***	***Code***		*1 D90*	*2 D99*	*3 D99.9*	*4 D99.99*	*5*	***Reference***
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6 CONCLUSIONS

- Double rooms
  - The achieved disinfection level is a reduction of 99.99% (4 logarithms) for most of the basins for which there are bibliographic studies.
  - The achieved disinfection level is at least a reduction of 90% (1 logarithm) for most of the referenced viruses, reaching levels of 99.9% (3 logarithms).
  - Based on the existing bibliography for the Coronavirus, radiation levels that are reached guarantee a reduction of 90% (1 logarithm). For this virus in particular, sensitivity similar to that of the E.Coli bacteria is estimated, so that by analogy levels of up to 99.99% (4 logarithms) should be reached.
  - The system has also allowed the reduction of a logarithm in spores and microorganisms.

- ICU Area
  - The achieved disinfection level is a reduction of 99.99% (4 logarithms) for most of the basins for which there are bibliographic studies.
  - The achieved disinfection level is a reduction of at least 99.99% (4 logarithms) for most of the referenced viruses.
  - Based on the existing bibliography for the Coronavirus, radiation levels that are reached guarantee a reduction of 90% * (1 logarithm). For this virus in particular, a sensitivity similar to that of the E.Coli bacteria is estimated, so that by analogy levels of up to 99.99% (4 logarithms) should be reached.
  - The system has also allowed the reduction of a logarithm in spores and microorganisms.

* There are currently no bibliographic data on the level of radiation required for **COVID-19.** Our radiation levels are **1000 times higher** on most surfaces than those documented for other types of coronaviruses.

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