STRATEGIC DESIGN RESEARCH JOURNAL

Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency

Carlos Alberto Nader Manrique [a] * | **Alex Leandro Pérez Pérez** [a]
Helmuth Geofre Ramos Calonge [a] | **Camilo Andrés Cifuentes Quin** [a]

[a] La Salle University, Faculty of Habitat Sciences: Bogotá, Colombia.
* Corresponding author: cnader@unisalle.edu.co

ABSTRACT

In response to the COVID-19 global pandemic, the Colombian Ministry of Science and Technology launched the call for research proposals "MinCienciatón". The call invited researchers in different fields to submit solutions that help to mitigate the health emergency produced by the spreading of the virus worldwide, including ideas for the isolation of infected patients and the protection of medical staff. In this context, the LAB LAHC1 was selected to produce a Portable Epidemiological Isolation Unit. A Product of the laboratory's research in polyhedral geometry and ephemeral architecture, we designed a pneumatic structure which allows for the treatment of infected patients as well as the isolation of medical staff and equipment. In the event that the health system becomes saturated, this system will allow the sanitary authorities to expand their hospital capacity when needed. It will also allow for the installation of field hospitals in isolated areas within the national territory that do not have the necessary infrastructure to cope with the sanitary crisis.

Keywords: Biomedical Design, Pneumatic Structures, Ephemeral Architecture, Polyhedral Geometry.

INTRODUCTION

According to the information provided by the Ministry of Health (2020), the Colombian government established a four-phase strategy to respond to the contingency produced by the Covid-19 pandemic. During the first two phases, the health authorities expect to treat infected patients in traditional health providing institutions. The third and fourth phases correspond to critical situations, in which it is expected that the health system will become saturated, and patients will have to be treated in provisional facilities adapted to cope with the contingency. According to this panorama, there is a general concern for highly populated zones that do not count with the necessary amount of Intensive Care Units to deal with a situation of elevated rates of contagion. Likewise, the situation is worrying in remote areas of the national territory that have low capacity health facilities or that simply lack of health provider care centers.

Taking into account the aforementioned context, it is very likely that at some point of the sanitary crisis the health authorities will have to adapt large covered areas (sports centers, exposition halls, warehouses, etc.) to create temporary care centers. In such spaces, it will be crucial to guarantee the appropriate spatial and functional conditions to treat infected patients and to prevent the spread of the virus.

As a contribution to the efforts made by national and local governments to face the emergency, we put into function of the current needs the results of previous experimental projects – related to lines of research in ephemeral architecture, non-conventional structures and polyhedral geometry. In response to the call MinCienciatón for research proposals launched in march 2020 by the Ministry of Science and Technology, we proposed the design and production of a Portable Epidemiological Isolation Unit (to which from now on we will refer to simply as PEIU). In accordance with the briefing of the call, PEIU is a device "for the management of patients with COVID-19 and other acute respiratory infections, guaranteeing the safety of health professionals" (2020).

Selected for funding by the Ministry of Science and Technology, PEIU is a system that allows for the construction of temporary health facilities based on concepts of flexibility, adaptability, portability, low cost and a fast track low-technology fabrication approach. These features of the proposed system are of particular interest in the current context because they allow for an expedite and low-cost manufacturing process, a simple assembly procedure that does not require specialized workforce for installation and maintenance, and the possibility to transport the isolation units to any place within the national territory. In addition, the designs allow for variations of size and shape which will let the system to be easily adapted to respond to the variable spatial conditions of the potential implementation sites.

PEIU is a pneumatic structure made of PVC fabrics, and it is composed of a series of 2 frequency icosahedral geodesic domes interconnected through cylindrical tunnels. This structure can be used both for the treatment of infected patients in aseptic and well-ventilated environments and for the isolation of medical staff and equipment exposed to the virus. Additionally, in agreement with the recommendations of the World Health Organization, the system will guarantee:

- Permanent surveillance of the confined space from the exterior of the domes.
- The possibility of adapting ventilators, hand washing equipment, purifiers or nebulizers, and other required medical equipment inside the domes.
- The connection to hydraulic and electrical installations in accordance with the requirements of field hospitals.

Next, we will present the project's background, the design methodology and concepts underlying the development of PEIU, its materialization process, and the preliminary results and conclusions of production of the system.

1. PROJECT BACKGROUND: SOME NOTES ON PNEUMATIC STRUCTURES

Pneumatic structures are defined as building systems whose shape and stability are determined only, or in great measure, by a pressure difference created by the injection of gases, liquids, cellulose or granular substances (Nader, 2019). These structures work by traction, they use the loads parallel to the membrane and convert them into parallel vectors that create tension on it.

Several explorations about pneumatic structures were made during the last century, but the research on this field began in the eighteenth century with the invention of the hot air balloon (Chi & Pauletti, 2005). In architecture and construction, pneumatic structures were

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

broadly used during the twentieth and early twenty-first centuries (Gomez-González et al. 2011). Some paradigmatic explorations about the use of pneumatic structures in the design of spaces include Frederick William Lanchester's pneumatic architectural system, developed in 1917, Walter Bird's development of large span structures, produced during the 1950's, Frei Otto's research about the formal configurations of pneumatic structures, as well as Dante Bini's creation of the Binishell system, which uses inflatable membranes as formwork for the construction of shells in reinforced concrete. Other paradigmatic researches on the use of pneumatic structures in architecture include the construction in 1970 of the U.S. pavilion in Expo Osaka, Norman Foster's design in 1971 of a temporary structure for the offices of CLT in England, and the development of vacuumatic structures by William A. Hanna and John Gilbert, which represents the latest theoretical advance in the field of pneumatic structures.

Throughout the twentieth and early twenty-first centuries, pneumatic structures have been largely used for military, emergency, exposition and storage purposes. Today, this type of structure is still used for covering large spans in warehouses and shopping malls, as well as in experimental buildings that combine the use of pneumatic structures and other building systems such as space lattices and wire meshes. Some paradigmatic examples of the contemporary use of pneumatic structures in the design of spaces is the Eden Project, by Grimshaw & Partners, and the Beijing National Aquatics Center, also known as Water Cube, designed and built for the 2008 Olympic Games by a consortium made up of PTW Architects, Arup, CSCEC and CCDI.

Pneumatic structures are usually constituted by a membrane (that can be fabricated with polymers), stiffening cables and ballasts that support and stabilize the structure, compressors or fans that inject and maintain air inside the structure, and air locks to prevent the loss of internal air pressure. These kind of structures can be of three types according to the magnitude and control of the pressure, and the direction of injection of the stabilizing fluid. The first type is constituted by low-pressure structures (supported with air). The second type includes high-pressure structures (inflated with air). The third type is composed by hybrid systems that combine low and high-pressure techniques. According to the direction of the injection of the fluid, pneumatic structures can be of positive pressure, if they are injected with a stabilizing fluid, or of negative pressure, if they work by means of the extraction of air (Figure 1).

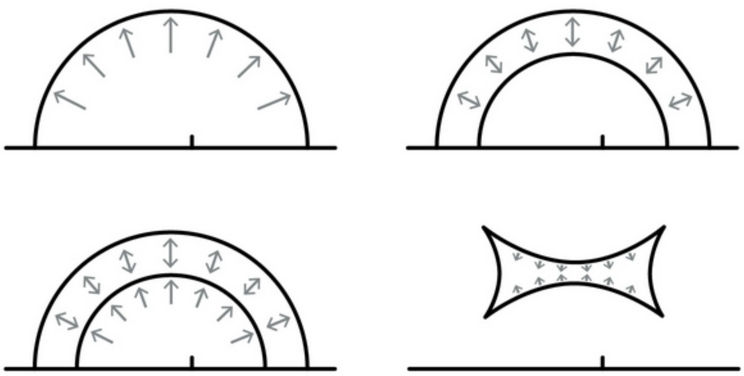

Figure 1. Four types of pneumatic structure: Low positive pressure, high positive pressure, hybrid (low and high positive pressure), high negative pressure.

Various aspects of pneumatic structures are of particular interest for the development of PEIU (which, accordingly to the classification of pneumatic structures presented above, is a

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

low positive pressure pneumatic envelope based on the use of membrane skins). As mentioned before, the current sanitary crisis will require the construction of temporary facilities that must respond, among other aspects, to criteria of portability, low cost and a low-technology fabrication approach. Crucially, pneumatic structures can be built with light and cheap materials, they can be produced rapidly, they are foldable, transportable and easy to install, and their construction and assembly doesn't require highly specialized machinery or workforce. These aspects permit to create large and light structures in little time with a relatively small budget.

2. DESIGN METHODOLOGY AND CONCEPT: LESSONS FROM NATURE

In recent years, the LAB LAHC has accumulated considerable knowledge and experience in the line of research of "nature and geometry". Following Buckminster Fuller (1982), who claimed that nature works according to minimum energy requirements and is the perfect result of what he calls "spatial compressions", we accept that the universal law of energy is that systems always seek and find their more efficient state and that in consequence, natural systems always find autonomously the most adequate spatial arrangements. For instance, superficial tension is responsible for some insect's ability to stand on water without drowning; of course, nobody explained insects the principle of superficial tension. In the same way, several natural systems discovered themselves that the spherical formation is the shape that can encapsulate the biggest amount of volume with the lowest possible surface area. Thanks to this universal principle, bubbles have the shape we know. According to the aforementioned natural law, the molecules that constitute the thin layer of the membrane of the bubble self-organize to find the most compact configuration (Wang et al., 2018). In this way, they achieve the form with the smallest necessary surface to enclose the quantity of air contained inside them.

By acknowledging the capacity of natural systems to find the most efficient and the smartest spatial solutions, we look at nature as a means to translate its functioning into a constructive language. This method is a means to explore spatial solutions adapted to the needs of the construction of the built environment. This approach is at the core of the development of PEIU, a project in which we explore concepts of polyhedral and synergetic geometry to solve efficiently the spatial needs of emergency structures.

Amongst regular polyhedral, the icosahedron is the one which shape is closer to that of the sphere, if one takes into account the relation between its surface and its volume (Coexter et al., 2012). An example of the efficiency of this shape is the shell of icosahedral viruses, which take a spherical shape to protect the genetic material with the lowest possible protein investment (Figure 2).

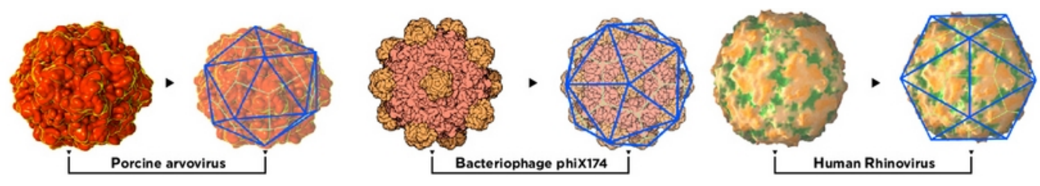

Figure 2. Icosahedral viruses: Porcine Parvovirus, Bacteriophage phiX174, Human Rhinovirus. Image adapted from: Kateryna Kon, http://pdb101.rcsb.org/motm/2; http://www1.biologie.uni-hamburg.de/b-nline/chimes/virus/introicos.htm

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

This kind of shape is ideal for the production of pneumatic structures for two reasons. One is the abovementioned efficiency of the icosahedron in terms of the relation between surface and volume. The second reason is that the triangulation of the surface reduces the load received by each one of its faces, because the seams that join them function as load transmitters that replace the use of cables. According to the above, the icosahedron offers two interesting features that suit two major needs of our briefing: low material consumption and stability. For these two reasons, we chose it as the basic spatial typology for the production of PEIU.

The icosahedron is the regular polyhedron more similar to the sphere, and it is the symmetric polyhedron that circumscribes the biggest number of great circles: G.C = (faces / 2) + (vertexes / 2) + (edges / 2) (Fuller, 1982). However, the icosahedron is not as efficient as the sphere. To achieve the highest efficiency of the shape, an icosahedron of frequency 2 was created accordingly to the steps described below (Figure 3):

- The icosahedron is inscribed into a sphere.
- The center of the sphere is found in a way that, under the conditions determined by the previous step, it coincides with the center of the icosahedron.
- Radial axes are drawn towards the surface of the sphere intersecting each one of the 30 edges of the icosahedron at its center.
- The intersection points are projected towards the surface of the sphere on the direction of the radial axes, thus generating two edges and one vertex out of each one of the pre-existing ones.
- The new 30 vertexes are connected to each other to generate 60 extra edges. Through this process, starting from the Icosahedron as a geodetic sphere of frequency 1 (20 faces, 30 edges, 12 vertexes), it is possible to obtain a geodesic sphere of frequency 2 (80 faces, 120 edges, 42 vertexes).

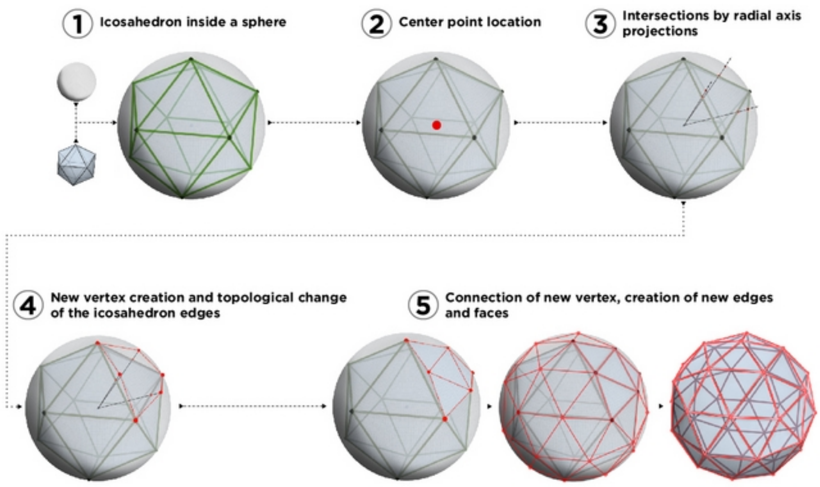

Figure 3. Steps for the creation of a geodesic sphere of frequency 2.

In this way, we created a shape that gets closer to the sphere's degree of efficiency; the above through the optimization of the integrity pattern of the geometry by describing 121 large circles. To obtain the dome, the resulting geometry is sliced into two equal parts using as cutting axis any of the 6 large circles coinciding with the planes described by the edges with the same length (Figure 4).

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

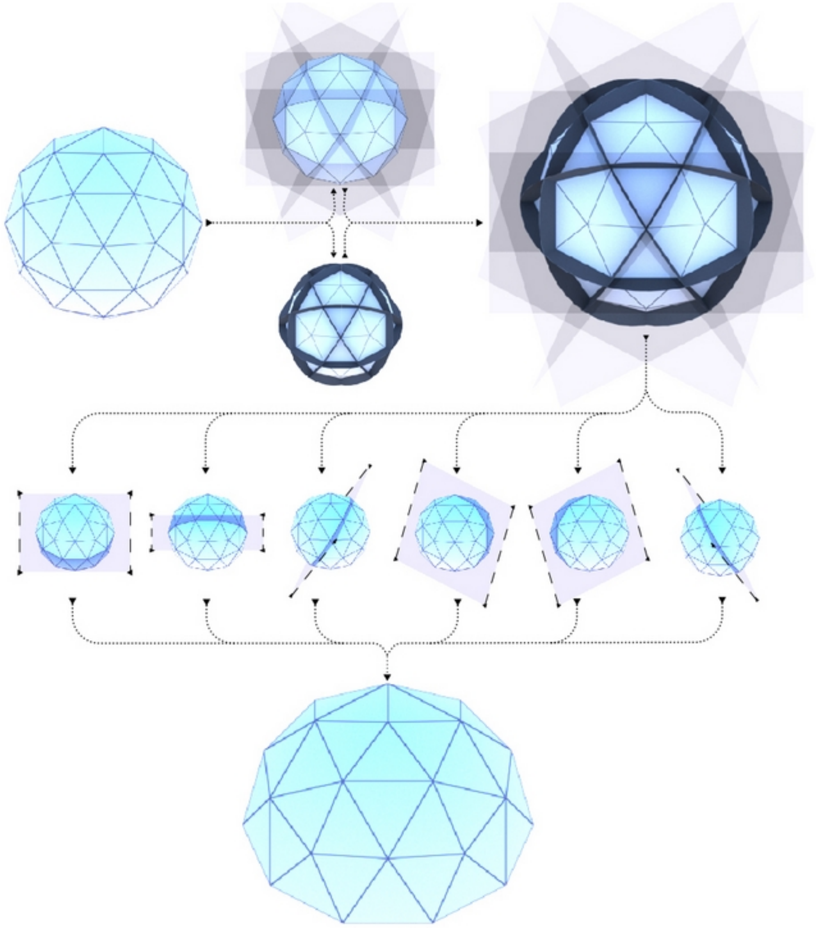

Figure 4. Creation of the dome through the slicing of the icosahedral geodetic sphere of frequency 2.

The resulting dome provides the geometry to create the isolation units. To create the full system, it is necessary to group and connect several domes in the most space-efficient way. As shown in Figure 5, since the sphere is an omnisymetric geometry, it permits the creation of packages of identical shapes for the maximal optimization of space.

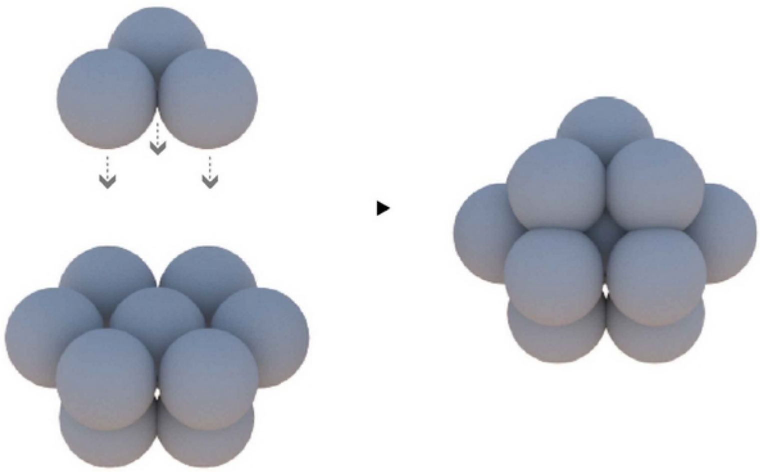

Figure 5. To create a package, six spheres are placed around one sphere, then three spheres are placed above and below.

Since all the isolation units of the system must be built directly on the ground, the form-finding process is focused on the search of the most efficient assemblage of several domes on a plane. This is made through the superposition of an hexagrid (made of regular hexagons of minimal diameter 5m) and the geometry of municipal sports centers in Colombia (which are the spaces where it is more likely to install PEIU when needed). The most optimal configuration is achieved through the grouping of thirteen domes in which the three central elements are replaced by a cylindrical shape that becomes the aisle that interconnects the whole system (Figures 6, 7 and 8).

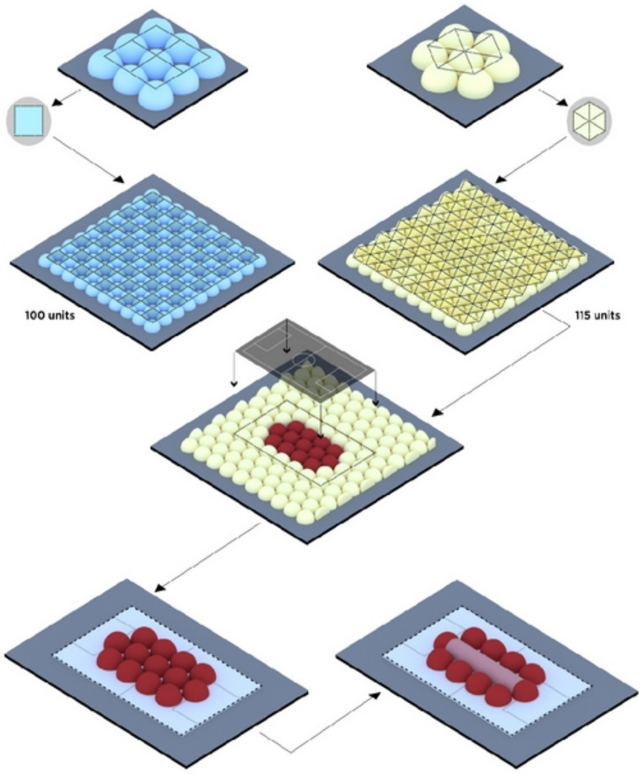

Figure 6. Form-finding process for the definition of the floor plan configuration of the system.

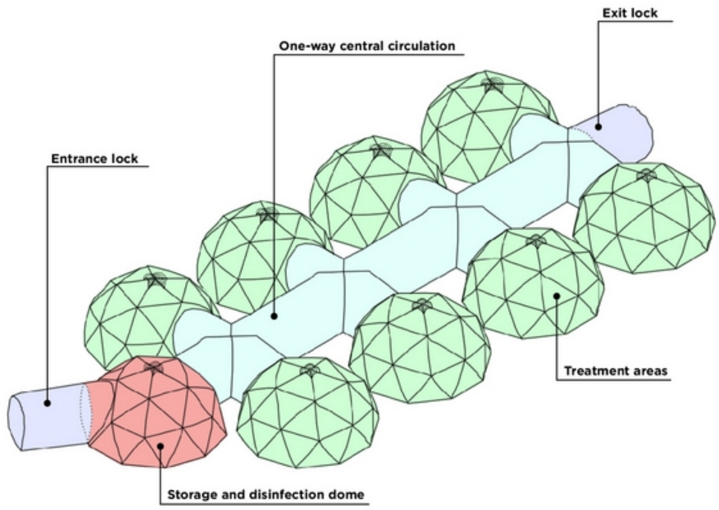

Figure 7. Axonometric view of an arrangement of nine domes connected by a cylindrical tunnel.

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

Figure 8. Rendering of a possible in-situ configuration of PEIU.

Although the most probable configuration of PEIU is the one described in figures 8 and 9, we have considered other possible design scenarios (Figure 9). As a matter of fact, the possibility of finding variable situations in the different contexts in which PEIU could be installed, requires the definition of a flexible design system. To achieve the flexibility of the design solutions, we have developed a parametric model that will allow us, when needed, to adapt the design solution to variable context requirements with little effort (Figure 10).

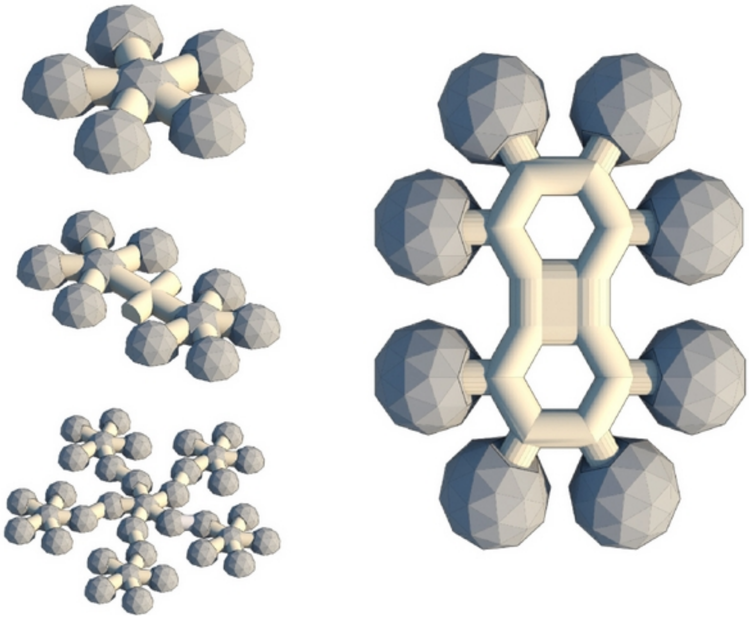

Figure 9. Alternative configurations of the system.

Defined products in Grasshopper

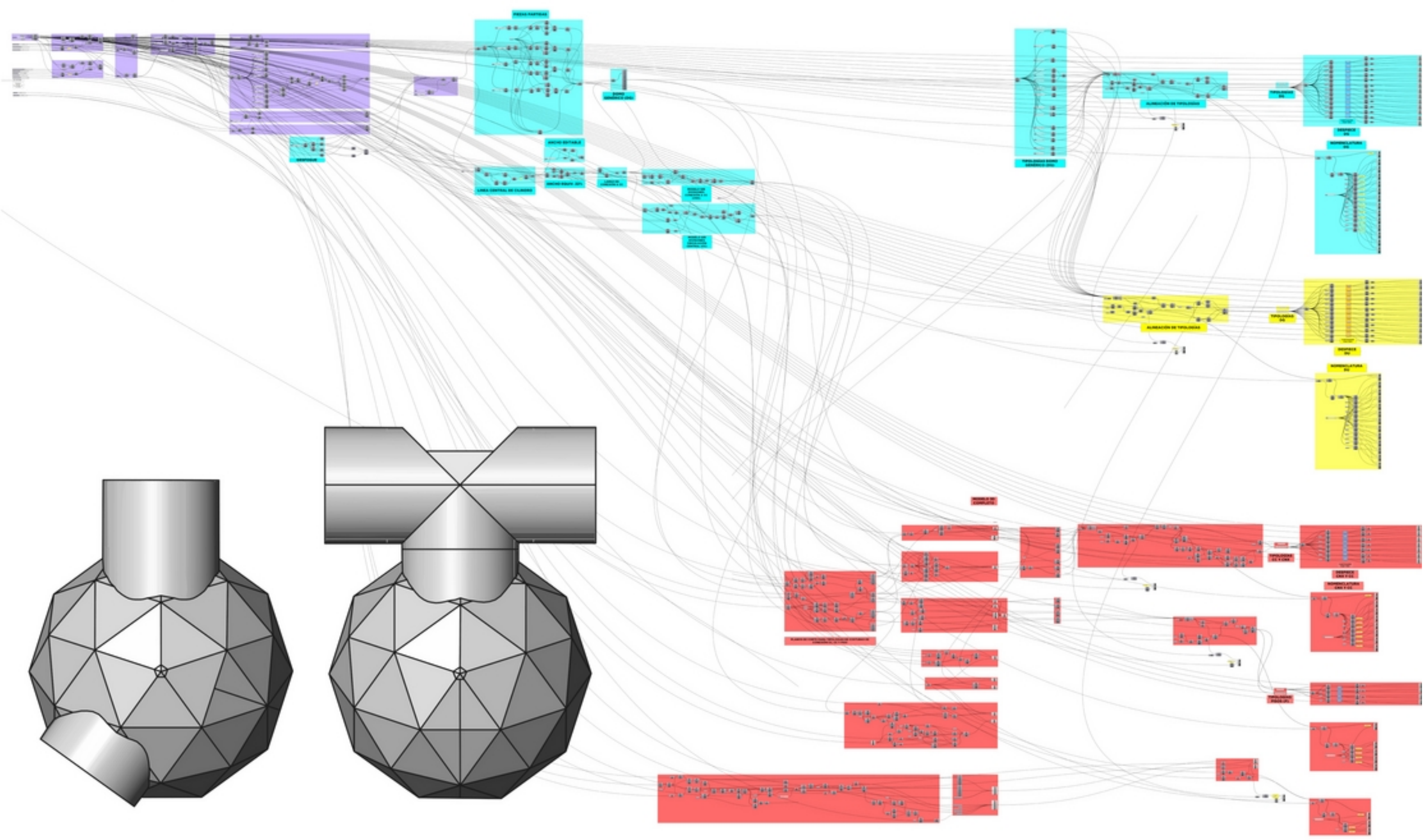

Figure 10. Generative algorithm in Grasshopper that allows the production of variable configurations of the basic geometry of PEIU. The design parameters allow for changes in the size of the dome, the configuration of the floor plan and the shape of the tunnels.

3. DESIGN REQUIREMENTS

After defining the basic geometry of the system, the detailed design of PEIU included various criteria related to the spatial needs for the treatment of patients, the ventilation and the quality of air inside the system, and the connection to electrical and hydraulic supply networks, required for the installation of medical and sanitary equipment into the isolation units.

According to the recommendations for the treatment of patients with infectious diseases, when it is not possible to locate the patients in individual spaces, it is suggested to place them in rooms shared with other patients having the same active infection, and to guarantee a spatial separation of at least one meter between patients and between patients and visitors. The diameter of the domes (5m) allows to locate in each module two beds with the corresponding medical equipment, leaving enough space to adhere to the recommended distances. Additionally, each dome has an internal division that works as an extra protection barrier and which guarantees a minimum of privacy for hospitalized patients (Figures 11 and 12).

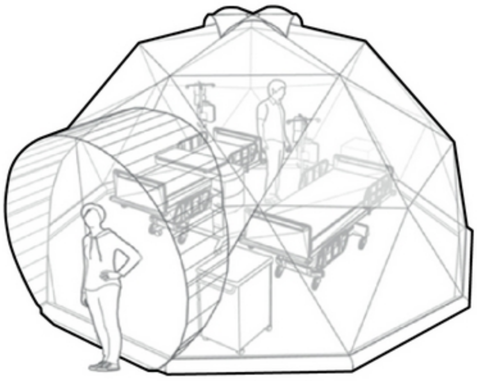

Figure 11. Distribution of the isolation unit according to the spatial criteria for the treatment of infected patients. Perspective view.

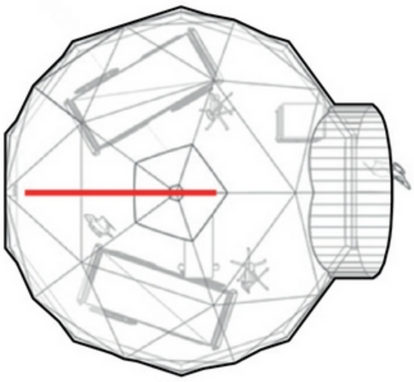

Figure 12. Distribution isolation unit according to the spatial criteria for the treatment of infected patients. Top view.

To guarantee the effective isolation of patients, the space inside the domes must be confined. Access is limited to carry out sporadic tasks, such as inspection and disinfection, and, for this reason, the correct ventilation of the module is an essential design aspect. The adequate ventilation of the system is achieved thanks to the injection of air from the outside by means of a centrifugal motorized fan. To guarantee the structural stability of the system, the volume of air that is injected must be replaced permanently. To do so, a vent opening at the top of the domes allows for the evacuation of hot air. In addition, to the preservation of the structural stability of the system, the renewal of air permits to keep an adequate temperature inside the isolation unit and, more importantly, to guarantee the good quality of the air inside it.

The quality of the air is directly related to the quantity of air exchanged. According to the recommendations of the World Health Organization, in order to guarantee the quality of the air in health facilities it is necessary to assure an ideal ventilation rate of 160 liters per second per patient (with a minimum of 80 liters per second per patient). In consequence, to achieve the recommended ventilation rate in the isolation unit, it is necessary to renovate the air of each dome at a rate of 576 m3 per hour. The total volume of the PEIU is 1.140m3 and it uses six centrifugal motorized fans that inject 6.840 m3 per hour. Since the system is composed of 9 domes plus the circulation tunnels, the actual ventilation rate per dome is of approximately 684 m3 per hour.

In addition, in order to assure that both the incoming and outgoing air is clean, it is filtered at the inlet and outlet points. Finally, in order to separate the domes from the aisles and to keep the structural integrity of the system when opened to enter or to leave it, both at the

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

entrance of the domes and of the tunnels a series of floodgates are installed that avoid the loss of air pressure when the system is opened (Figures 13 and 14).

Regarding the installation of sanitary and medical equipment inside the isolation units, it is necessary to allow for the connection to electrical and hydraulic supply networks. For this reason, each dome includes a piece that functions as an interface between the inside and the outside (Figure 15).

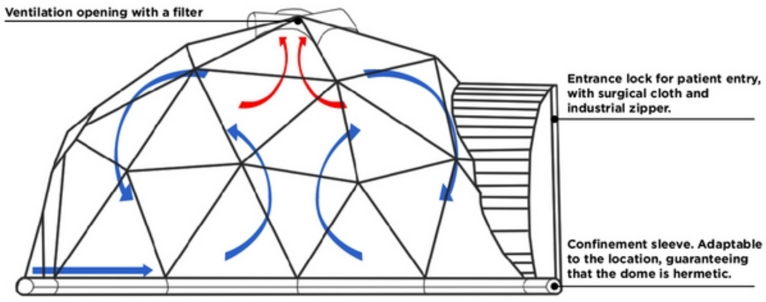

Figure 13. Air circulation system inside the isolation unit. Left view.

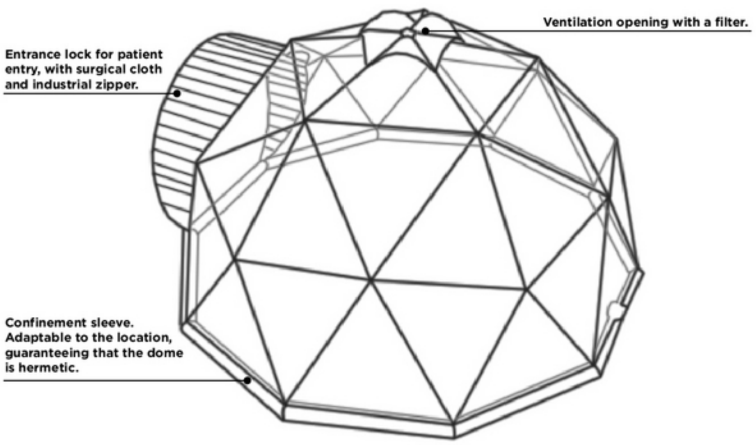

Figure 14. Main components of the isolation unit. Perspective view.

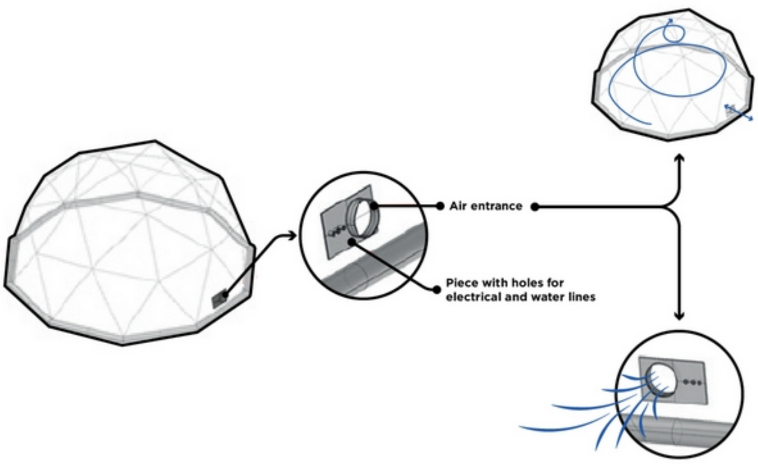

Figure 15. Interface piece for the connection to motorized fans and electrical and hydraulic supply networks.

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

4. MATERIALITY AND MANUFACTURING

In response to the needs of the system, the structure is entirely fabricated with polyvinyl chloride (PVC) fabrics of varying caliber and transparency. This material was selected because it is both malleable and resistant, easy to clean and fully recyclable, and it is used for the construction of all the envelopes of the domes and tunnels. The seams are machine stitched, and the sluices and doors are made with high traffic zippers and reinforced with detachable fiberglass rods to stiffen them.

After the definition of the appropriate geometry and integrity pattern of the structure, the exploded/explored assembly is produced (Figure 16). These drawings can be used to make mold templates to trace the patterns on the material (when hand cut), or they can be transferred directly to a laser cutting machine (when this technology is available). This means that both cutting and patterning can be performed in an analogous way, by means of digital manufacturing processes, or through hybrid options. In this sense, the construction process can be adapted to the conditions of the manufacturing environment.

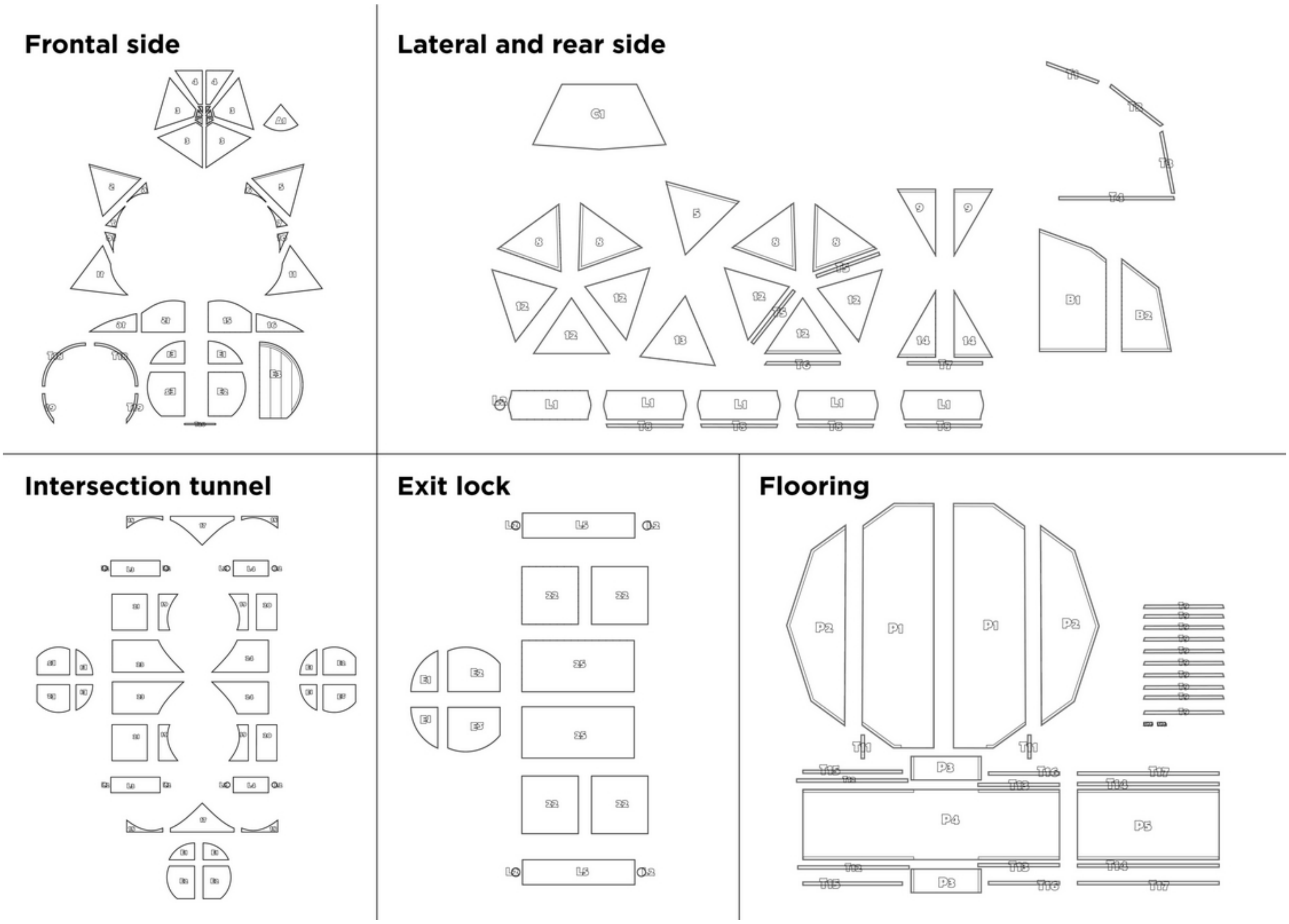

Figure 16. Exploded assembly of the basic constructive elements.

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

To make the domes, it is necessary to join the 30 isosceles triangles to make a series of pentagons. These pentagons are connected between them through the vertexes, and the remaining spaces are filled with the 10 equilateral triangles (Figure 17). To build the tunnels and the floor, the different parts of the floor are joined according to the assembly pattern and then stitched to the domes and to the tunnel. The system is sectioned into five large units that are connected amongst them at the time of assembly by means of hook and loop closures (Figure 18).

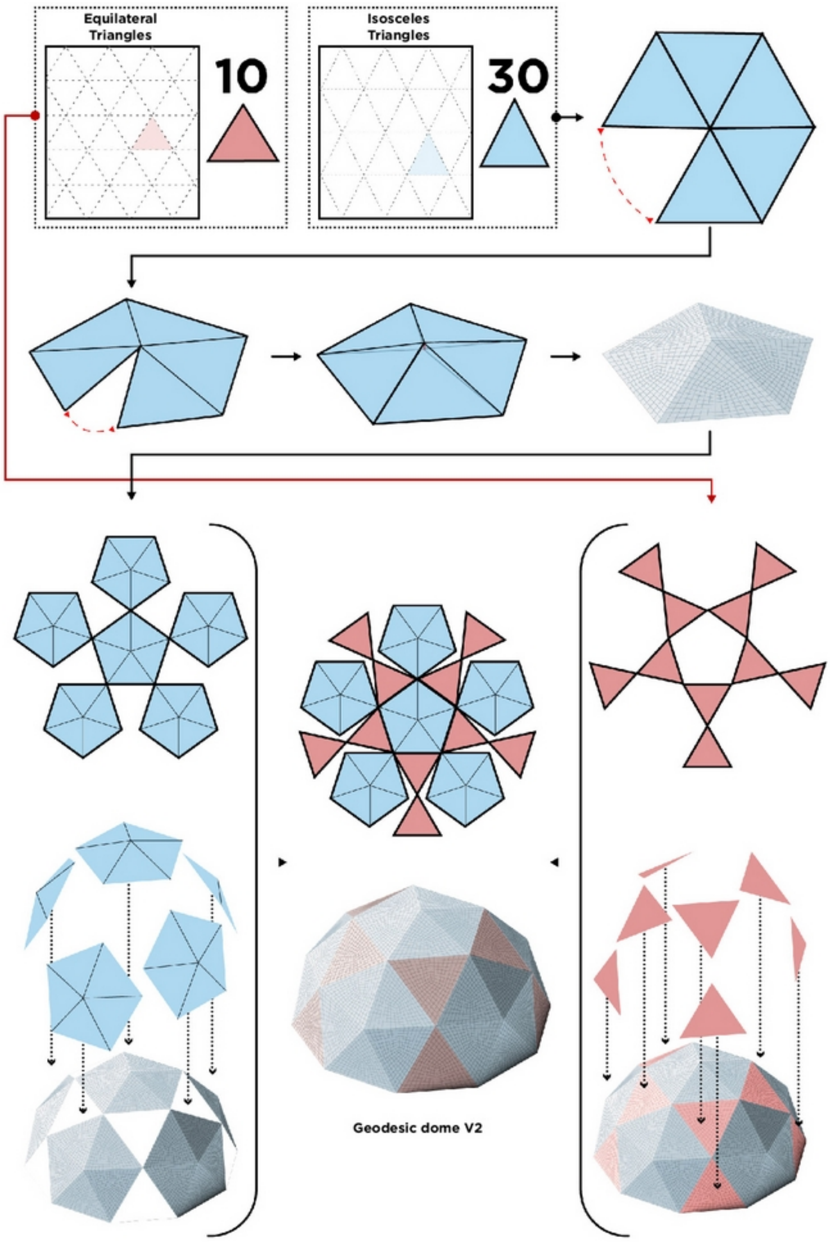

Figure 17. Building instructions for the assembly of the dome.

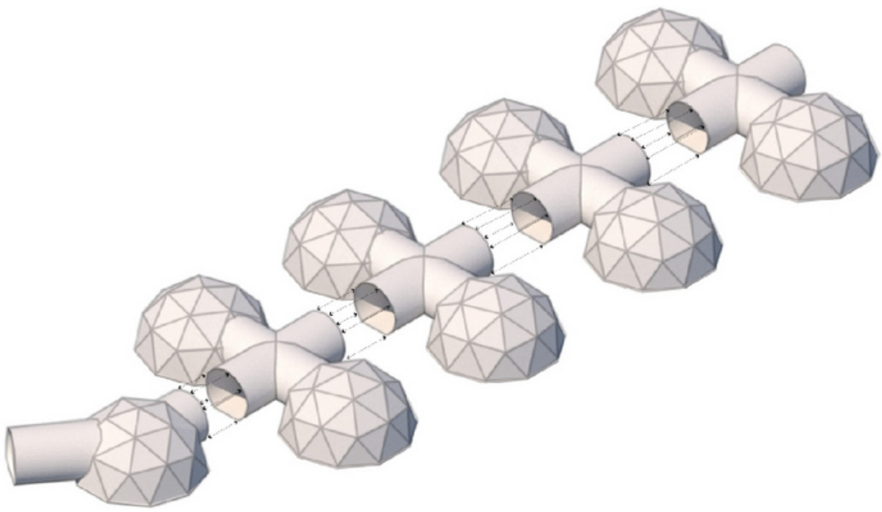

Figure 18. Sectioning of the system into five larger modules.

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

After being assembled, the structure is inflated and stabilized with air driven by 0.5 horse power centrifugal fans with a flow rate of 16 m3 per minute. The stabilization of the structure (Figure 19) is complemented by the seams (which function as a stiffening wire mesh), the confinement sleeves located at the bottom of the domes and tunnels (which are filled with water to add weight to the structure), and the anchoring elements (which allow to attach the system to the existing structure at the installation site).

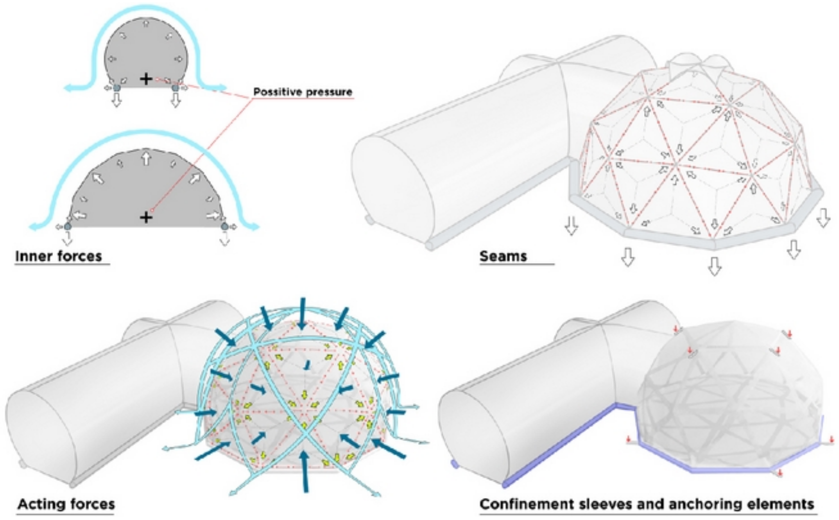

Figure 19. Stabilization system of the pneumatic structure.

5. PRELIMINARY RESULTS AND CONCLUSIONS

Through a feedback process that involved the assessment of various one-to-one scale prototypes of the system and the corresponding adjustment to the designs, we validated the overall design concept, and we were able to collect a great amount of quantitative and qualitative data regarding the manufacturing process and the functioning of the system (Figures 20, 21 and 22).

Figure 20. One-to-one scale prototype of the basic construction module of the system.

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

Figure 21. One-to-one scale prototype of the entire system.

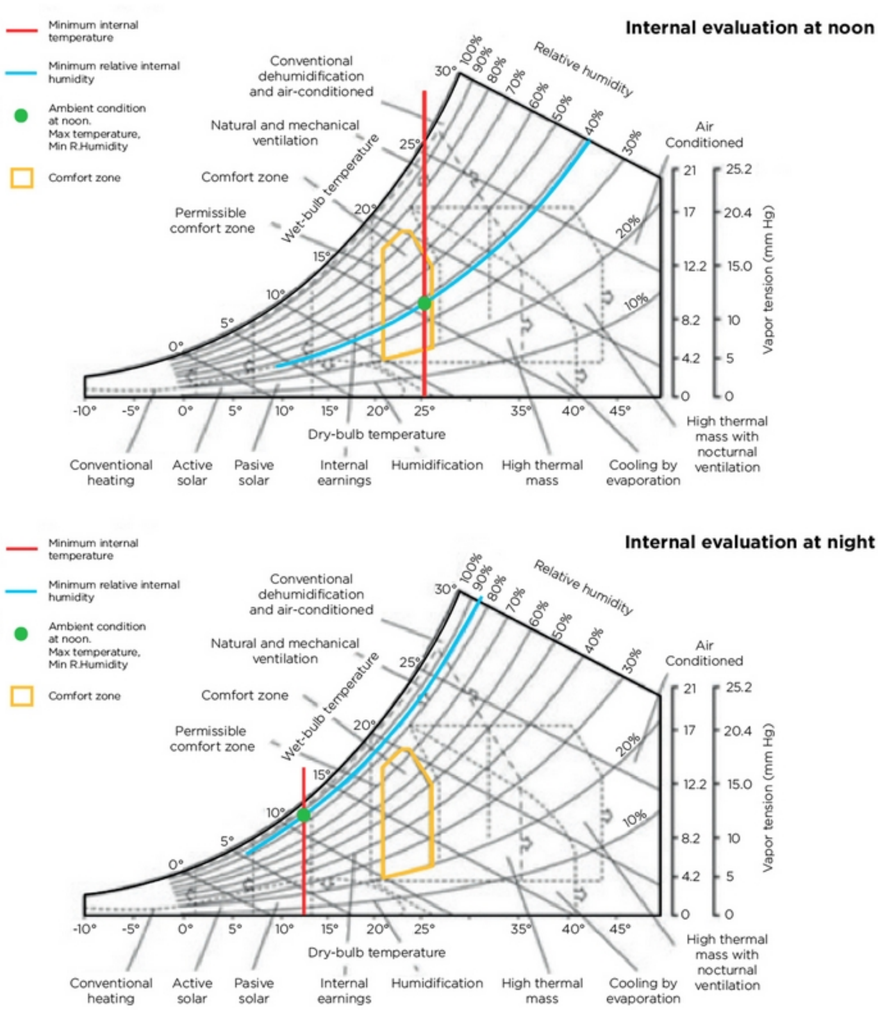

Figure 22. Analysis charts of the habitability conditions inside the isolation units.

By means of the abovementioned feedback process, we could identify a series of aspects which improvement rebounded in a more efficient building and assembly system and ameliorated the performance of the PEIU. These enhancements involved solutions to improve the portability of the isolation units, to simplify the joints between its composing elements, to reinforce the stability of the structure, and to improve the habitability conditions inside the space/dome (Figure 23).

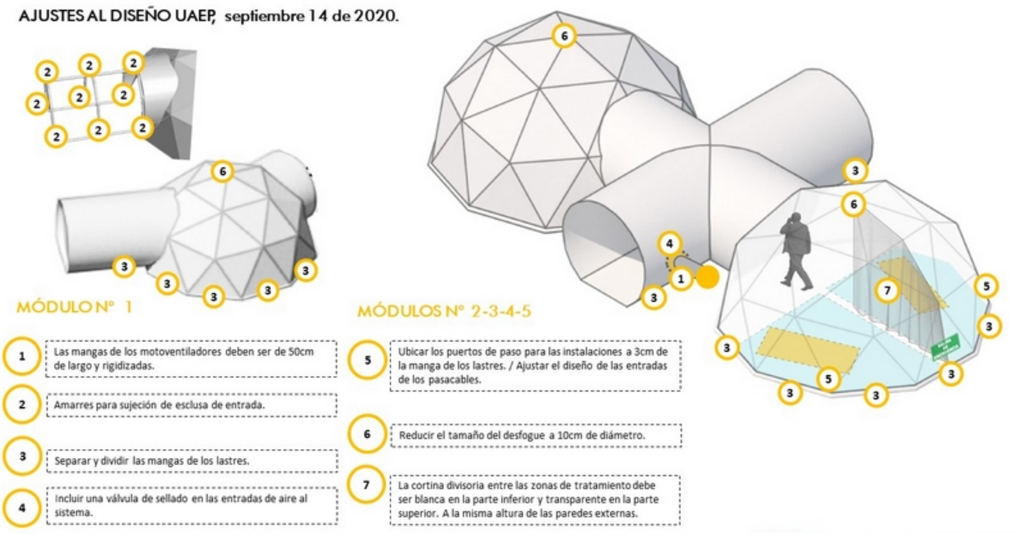

Figure 23. Assessment chart of the prototypes.

After these enhancements, we consider that the PEIU has reached the TRL level 8 of the "Technology Readiness Level" measurement system (Tomaschek et. al, 2016). The foregoing means that the project has been tested and approved, and that it is ready for its implementation. However, due to the evolution of the pandemic in Colombia, the isolation units have not yet been used for the treatment of patients in provisional health facilities. In consequence, to date we do not have data about the performance of the PEIUs under the conditions of the third and fourth phases of the strategy established by the Colombian government to respond to the contingency produced by the Covid-19 pandemic. Currently, the isolation units requested by the Ministry of Science and Technology are being manufactured, and the patenting process of the system is underway. The implementation strategy is being studied along with the Ministry of Health and the National Army, which will be in charge of the transportation and installation of the units in different parts of the territory.

In the current context, in which the Latin America region and the Caribbean represent 22.92% of the total reported cases globally (Inter-American Development Bank, 2020), we expect that the development of PEIU will allow the Colombian sanitary authorities to expand its hospital capacity when needed. We also expect that this kind of initiative, which bonds academia and the public sector in the search for design solutions to the pressing needs of our time will endure. More importantly, we expect that this joint effort will become a means not only to solve the emerging problems of a hyper globalized society, but a means to imagine an alternative future in which the search for answers to a global pandemic, global warming and global precariousness will not be a design issue.

ACKNOWLEDGMENTS

The members of the LAB LAHC would like to thank several institutions and people whose help has been crucial for the development of the project: the Ministry of Science and Technology and the Colombian National Army; at La Salle University, the staff of the Faculty of Habitat Sciences and of the Vice-rectory for Research and Transfer, especially Fredy Alejandro Martinez, Alexandra Prada and our dedicated research assistants Ruth Amelia Cala, Nicolás Pardo and Felipe Diáz; and, last but not least, Hugo Quintero and his team for the technical support.

REFERENCES

Coxeter, H. S. M., Flather, H. T., & Petrie, J. F. (2012). *The fifty-nine icosahedra*. Springer Science & Business Media.

Chi, J. Y., & Pauletti, R. M. O. (2005). An outline of the evolution of pneumatic structures. In II Simposio Latinoamericano de Tensoestructuras, Caracas.

Fuller, B. (1982). *Synergetics: Explorations in the Geometry of Thinking.* New Jersey. Prentice Hall & IBD.

Gómez-González, A., Neila, J., & Monjo, J. (2011). Pneumatic skins in architecture. Sustainable trends in low positive pressure inflatable systems. *Procedia Engineering,* 21, 125-132. DOI: 10.1016/j.proeng.2011.11.1995

Inter-American Development Bank. (2020) COVID-19: Situation update in Latin America and the Caribbean. Retrieved November 9, 2020 from https://www.iadb.org/en/coronavirus/current-situation-pandemic

Ministerio de Ciencia y Tecnología. (2020). Invitación a presentar proyectos que contribuyan a la solución de problemáticas actuales de salud relacionadas con la pandemia de COVID-19 (Invitation to present projects that contribute to the solution of current health problems related to the COVID-19 pandemic). Retrieved April 1, 2020, from https://minciencias.gov.co/convocatorias/invitacion-para-presentacion-propuestas/invitacion-presentar-proyectos-que-contribuyan

Ministerio de Salud y Protección Social. (2020). Coronavirus (COVID-19). Retrieved April 1, 2020, from https://www.minsalud.gov.co/salud/publica/PET/Paginas/Covid-19_copia.aspx

Nader, C. (2019). *Arquitectura Alternativa Sostenible* (Alternative Sustainable Architecture). Bogotá. Ediciones Unisalle.

Organización Panamericana de la Salud. (2011). Manual de control de infecciones y epidemiología hospitalaria. Washington (Infection control and hospital epidemiology manual. Washington). Organización Panamericana de la Salud.

Tomaschek, K., Olechowski, A., Eppinger, S., & Joglekar, N. (2016). A Survey of Technology Readiness Level Users. In INCOSE International Symposium (Vol. 26, No. 1, pp. 2101-2117).

Wang, S. P., Zhang, A. M., Liu, Y. L., Zhang, S., & Cui, P. (2018). Bubble dynamics and its applications. *Journal of Hydrodynamics,* 30(6), 975-991. DOI: 10.1007/s42241-018-0141-3

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09