
COVID Testing Station
BDS

Mobile and Portable Specimen Collection Unit

with Biosafety Features and Other COVID-Related Design Responses

Text by Richard Martin Rinen, John Ernest Jose, and Cristopher Stonewall Espina

This research paper is a narrative on the conceptualization of a Specimen Collection Unit (SCU) as a proposed design solution for conducting Oropharyngeal (OP) swab and Nasopharyngeal (NP) swab tests. The paper also includes other designs, such as the Virus Trap and Isolation Pods, designed to control the spread of the coronavirus. The SCU was developed to address the systemic issues during the pandemic, such as suspension of public transportation, lack of healthcare workers, overcrowding of hospitals, scarcity of personal protective equipment (PPE), and risks of contagion. The SCU combines the efficiency of collecting as many swab tests as possible and accessibility by making the swab tests available without needing patients under investigation (PUI's) to leave their vicinity. Prior consideration was given to the safety of healthcare workers by applying the concepts of negative and positive air pressure and by ensuring minimal physical contact between the healthcare worker and the patients. For collecting tests, the SCU would first identify its deployment location and time to maximize the sample collection capacity. The SCU management team shall coordinate with the LGUs and traffic authorities for proper clearance, scheduling, and deployment locations. Next, the SCU would be deployed to various barangays to collect samples and contact information, and notification of the results can be forwarded to the LGU, posted online showing only patient numbers for anonymity, via text message to the patients, or a combination of any of the steps. Two models of the SCU were developed. One is Mobile (MSCU), and the other is Portable (PSCU). On the one hand, developing a single MSCU vehicle is projected to cost around 2 million Pesos, including retrofitting. The cost does not consider the vehicle's maintenance and fuel costs. The time needed to retrofit the base vehicle must still be determined. The PSCU, on the other hand, costs around One Hundred Twenty-Five Thousand per unit, including the biosafety features deployed. The time to fabricate a single unit takes three days, and assembly takes about thirty minutes or less. Aside from the SCUs, the Virus Trap was also designed to be used to isolate patients and suspected infected patients in their rooms to prevent the virus from spreading further outside of their isolation quarters. Another design, the Isolation Pods or Transporter, was

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developed to minimize physical contact between patients and health workers during transport from home or within the hospital. Students and faculty from the UP College of Architecture and UP College of Public Health conceptualized these design ideas around April 2020, when COVID-19 started spreading in the country.

I. Project Background

As of September 20, 2021, the Philippines has experienced two notable waves in COVID-19 cases in 2021. According to statistics by John Hopkins University, the first one peaked on April 15 with a 7-day average of 11,405 cases. Meanwhile, the second wave is taking place this September as of writing, with its current peak on September 15, having a 7-day average of 21,287 cases. August 30 also had the highest daily tally of COVID cases ever at 27,887.[1] The massive number of cases had placed great stress on healthcare facilities, especially in Metro Manila, with an even greater number awaiting test results or undergoing mandatory quarantine.

In 2020, the situation was no different. The government imposed a ban on public transportation in Luzon during the ECQ period, and private vehicles could only have one person inside.[2] This caused great inconvenience for most people who relied on public transportation to work.

The restrictions that accompanied the ECQ and the spread of COVID-19 presented several problems. First, as healthcare workers themselves got infected or even succumbed to COVID-19, this put a strain on the capabilities of hospitals due to a lack of human resources. [3] [4] Doctors and nurses being quarantined or coming down with the virus themselves clamor for their safety and protection. [5] Private individuals and companies were pooling together resources to donate PPEs and other supplies. However, PPEs were merely the last line of defense, and even greater focus should be given to engineering controls and reduction of physical contact with patients, particularly those who are asymptomatic carriers.

Aside from the dwindling number of available healthcare practitioners, the lack of professionals with training and experience in handling infectious substances was a problem that had been around before the outbreak. Even when additional infrastructure is made available, there is currently a small pool of professionals who could be deployed, as a majority of Filipino nurses would rather work in foreign countries. [6]

While door-to-door testing was a possible way for conducting mass testing, it was physically exhausting for healthcare workers and not efficient in terms of number of tests per day. This was also very uncomfortable for healthcare workers who had to wear PPE as the Philippines has a hot and humid climate. An alternative to this was permanent testing booths, which were also deployed for mass testing but were location-dependent. People who were far from these booths would have difficulty accessing them, and this was compounded by the suspension of all forms of public transportation during that time.

Due to the lack of public transportation during the ECQ, it was inferred that to make mass testing more accessible to the public, the testing centers should be the ones to come to the people. This could be done by making the testing centers "mobile" or "portable." These testing centers could be housed in a van that could travel to barangays and reach those who were far away from the accredited testing centers or get installed and disassembled in a matter of minutes.

It was also recommended by the WHO that mobile testing centers be set up in more remote areas, as testing centers were usually located in or near capital cities.[7] In the same way, portable testing booths are easily assembled and disassembled on sites near the communities and can be transferred easily from one community to the next.

II. Project Description

Due to the constraints mentioned, it was inferred that the best course of action to increase COVID-19 testing capability was to make it mobile or portable. This was the starting point in designing the Mobile Specimen Collection Unit or MSCU. It combined the strength of door-to-door testing (accessibility) and testing booths (efficiency). The MSCU and PSCU were designed in such a way that the healthcare worker inside the booth does not need to leave the vehicle or the booth they are in.

It also minimizes the number of healthcare workers required, as one MSCU could cover several barangays. Meanwhile, the Portable Specimen Collection Unit (PSCU) was designed to be easily built and deployed in high-population areas to decongest healthcare facilities. The PSCU could also be deployed in nearby hospitals or testing laboratories to expedite specimen testing.

The greatest advantage of the Specimen Collection Unit, as the name implies, is its mobility and portability. The SCU could be easily deployed to the Barangays. The LGU could request COVID-19 MSCU to be transported to any available open space, such as parking, plazas, or nearby Barangay Health Clinic and hospitals. A safe passage or dedicated lane could be coordinated with the LGU/MMDA to assist in the transport of the samples, reducing time delay, void, or repeat procedures.

Before the collection, studies showed that a route should first be identified to maximize the efficiency of the SCU in collecting samples. [10]

In terms of human resource allocation, the COVID-19 MSCU could be developed into a small unit of 2-3 healthcare worker teams or a larger unit, depending on the need.

In addition, the PSCU can be easily assembled and disassembled to cover more areas. As soon as the SCU has completed its target number of swab tests, it could proceed to another area or locality or return to its partner laboratory as needed.

With the Specimen Collection Units in place, the subnational laboratories will be able to focus on running the tests and not worry anymore about collecting swabs. Emergency rooms need no longer be congested by potentially infectious patients.

Designing the Mobile Specimen Collection Unit (MSCU)

Screening would first be administered one-on-one by a licensed professional. Pertinent data and initial examination of the patient would be conducted at this stage, including screening for symptoms, prior exposure to confirmed COVID-19 patients, and travel history. A temporary setup of a table, chairs, and necessary health monitoring equipment would be located inside an existing facility, such as a gym or covered court.

After the initial screening, the patient waits for his turn and then proceeds to the sample collection outside the SCU. The health professional would be staying inside the sealed SCU, and swabbing would take place. The healthcare worker administering the swabbing would seal the specimen and place it in a basket or cubby hole on the patient's side of the booth. An aide would collect it and then pass it on to the restricted area.

Inside the restricted area, the sealed specimen would be handled carefully by established standards for handling infectious samples. The passbox would be adjacent to a counter that would always remain empty whenever specimens are delivered. Another counter would be

Figure 1. Exterior Perspective of the Mobile Specimen Collection Unit or MSCU.

made available for sorting and packaging of the sealed specimen into approved insulated containers.

The result of the examination would be handled by the laboratories involved. They would have the option to post the result online, showing only the patient number for anonymity, send a text message to the patient, inform the LGU of the results in their area of jurisdiction, or a combination of the three.

The van would be compartmentalized to minimize contact between the patient and the healthcare professionals. The patients are physically separated from the person taking the swab. The patient remains outside the van while the health professional stays inside, making the healthcare compartment permanently sealed. The medical aide, who goes outside to assist patients, is also physically separated from the healthcare workers. During travel, the medical aide, the driver, and the healthcare worker are also physically separated to avoid possible infection.

Materials and connection joints should follow best practices that would allow easy clean-up of the space. Since it is not recommended to allow the patient to handle the collected specimen, a trained aide will collect the sealed specimen to reduce the risk of tampering, breakage, and stealing.

The inside of the MSCU van has positive air pressure through the use of an AC unit to prevent the virus and other contaminants from entering the vehicle. If there are leaks or if doors are to be opened, the air inside the vehicle would be forced out, rather than allowing outside air to come in, a design strategy similar to positive and negative air pressure rooms in hospitals.[8]

The staff area contains a wall-mounted folding chair, wall clock, hand sanitizer, bar stool, and trash bin. A worktable with a barstool is also placed inside the vehicle to allow the healthcare worker to do paperwork and necessary swab test preparations.

Meanwhile, patients could interact with the healthcare workers through the sealed glass window from the side of the MSCU. This is where patients can have their swab tests as gloves and a stethoscope are mounted on the sealed glass window, eliminating any forms of physical contact. Communication between the patient and the healthcare worker is done through a communication device with a “press to talk” operation that only operates on the healthcare worker’s side. This was akin to the testing booths in South Korea.[9] There is also a trash bin outside the vehicle where wastes from the procedure can be disposed of.

The height of the MSCU was designed in such a way that the healthcare worker should be able to stand upright inside the vehicle without slouching. At the same time, a step-up ladder can be provided to offset the height difference between the healthcare worker and the patient. LED-call signage is also placed outside the MSCU near the extraction area for patient queueing or announcements. The work area is also fitted with wall clocks, a worktable with convenience outlets for laptops, and a wall-mounted trash box.

Meanwhile, various space-saving measures are also designed within the interiors of the MSCU. A stool can be placed under the counter when not in use. A foldable chair for the health care worker and various overhead cabinets are placed to serve as storage for personal belongings and laboratory paraphernalia. Both the passenger seat area and the driver area have a wall-mounted cabinet for their personal belongings.

Collected Oropharyngeal (OP) swabs and Nasopharyngeal (NP) swab samples can easily be transported to different affiliated testing laboratories. By going closer to the households, rather than having people travel to the testing centers, there would be a reduced risk of

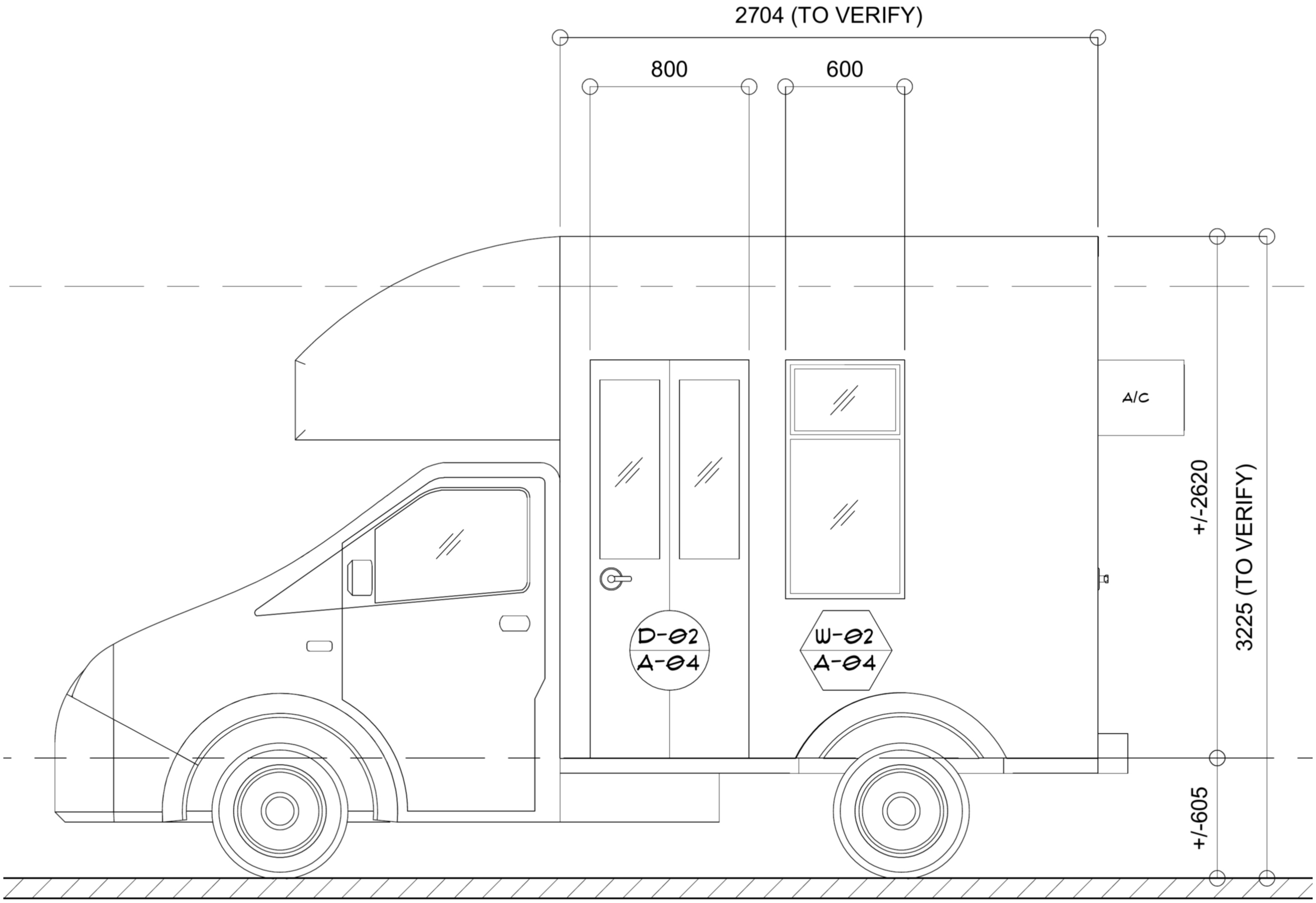


Figure 2. Side elevation of the MSCU.

community transmission. It was further inferred that for the testing centers to work, they should take into consideration the safety of the healthcare workers as they should not be exposed to the risk of being infected by the virus.

Learnings from the MSCU Project

Due to social distancing concerns, members of the MSCU Team would only be able to meet and communicate virtually through messaging apps such as Facebook Messenger or Viber. The task was delegated to different teams. Some were working on the design and retrofitting of the mobile unit, including the study of the motions involved in doing a procedure and anthropometrics, the mechanical design of clean rooms, the design of mobile emergency electrical systems, the process of decontamination, the provision for utilities, and the management of waste.

Most of the initial research had been done online as it was the most instantaneous way of gathering information for a project that was time-sensitive, and field research was not possible due to the onset of the pandemic. Guidelines from the DOH, design solutions from other countries, and the background of each MSCU Team member were key in finalizing the design.

Prior research was also done before designing the project; the MSCU Team took inspiration from the design of South Korea's swab booth as a basis for how patient-staff interaction would take place.

The project[11] had resulted only as a proof of concept. Most companies that expressed interest were willing to give financial support towards the project. They, however, required that the project be supported by the Department of Health (DOH) and the Research Institute for Tropical Medicine (RITM). Neither establishment was able to respond to the MSCU Team's request to check the design and give approval.

Funding and institutional support were the greatest drawbacks that the MSCU suffered from. While many corporations expressed interest in funding the project, they hesitated, pending approval by the DOH. The team tried to reach out to DOH officials but gained no reply. As for the funding, the project required a projected amount of 2 million pesos as a base vehicle that needed to be retrofitted. Costs for vehicular maintenance and fuel were not yet taken into consideration. The MSCU also needed fabrication time for vehicle modification to transform the unit and required external support for utilities. The time needed to retrofit the base vehicle would still depend on the contractor based on various inquiries with various vehicular modification shops.

Future conflicts could also arise when it is time to sell the MSCU, as its resale value would depreciate.

However, there were ways in which the concept of the MSCU was realized, including the Swab Cab, a project spearheaded by then-Vice President Leni Robredo. The Swab Cab had its initial rollout in Malabon, Quezon City, and Imus, Cavite (Sarao, 2020) [12].

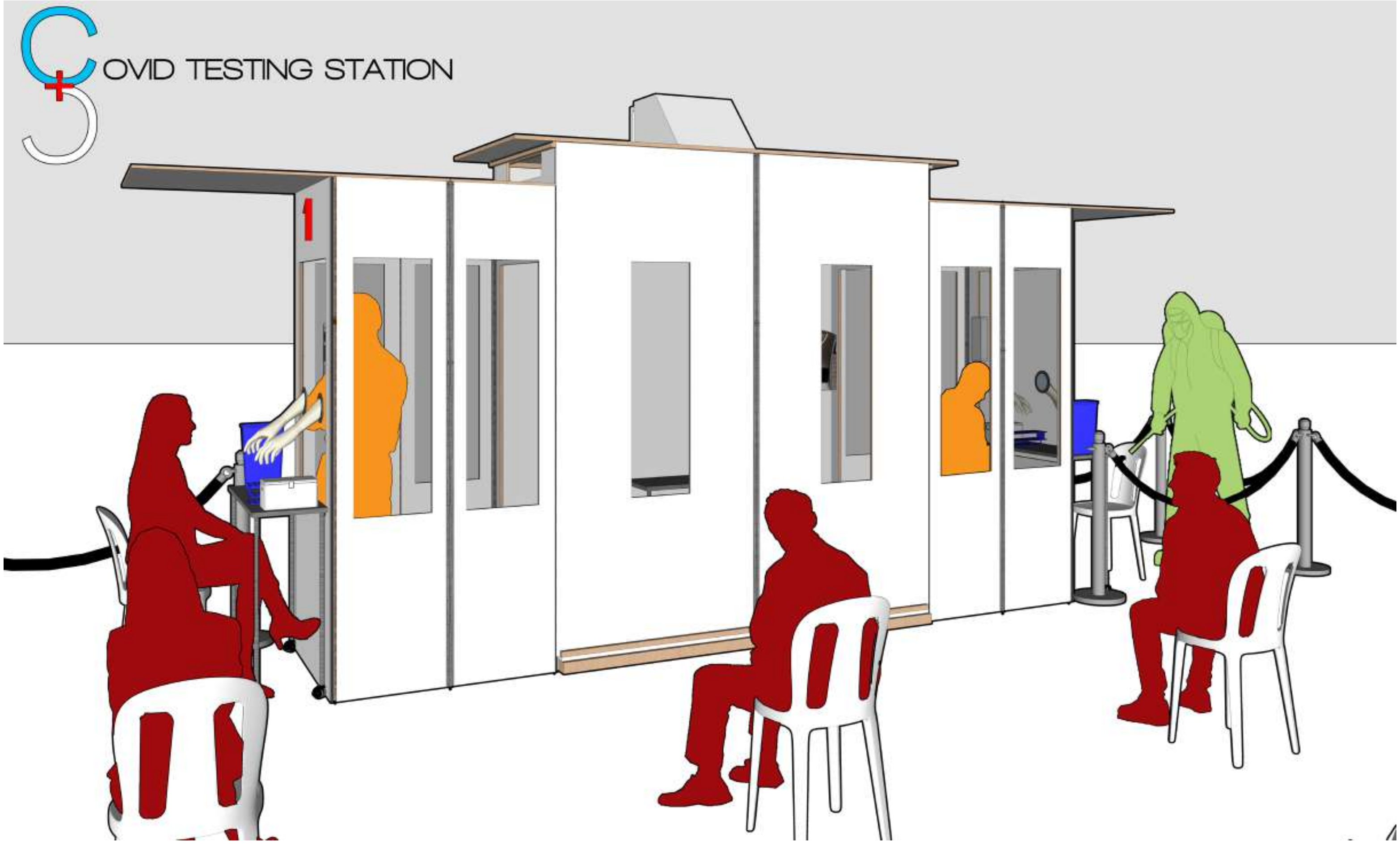


Figure 3. Exterior Perspective of the Portable Specimen Collection Unit or PSCU.

Designing the Portable Specimen Collection Unit (PSCU)

With the same principles as applied to the MSCU, the PSCU was designed to be deployed to hospitals for additional specimen collection capacity, to public places like barangay halls, basketball courts, and other multi-purpose areas where mass gathering with proper social distancing is possible to bring mass testing closer to the people.

The advantages of the PSCU are the following:

1. Each unit can be fabricated in three (3) days.
2. Foldable and can be assembled in 30 minutes.
3. Inexpensive.
4. Easily replicable.

The PSCU is composed of two swabbing booths with a vestibule in the middle that serves as the preparation space for the health worker as well as a transition and airlock area for maintaining the correct air pressure. The design follows the principles used in designing the MSCU. Positive pressure is maintained using an air conditioning unit located on the roof of the vestibule. This will push the air out when the door is opened. It also makes the temperature inside the booth comfortable for the Health Workers. An air filter using ultraviolet light is placed inside each booth to make sure that air is filtered and kept safe from virus contamination. Furthermore, exhaust fans with automatic closing mechanisms are placed at the booths to force the air out when needed while the door at the vestibule is closed to prevent the air from being sucked in through the door. Although no other testing methods or equipment to measure the pressure were used, a smoke test was performed to verify if this would work. The test was successful; the smoke went out whenever the door was opened.

Learnings from the PSCU Project

The PSCU project started as a personal initiative from one of the co-authors, and social media also played a very important role in facilitating the coordination between designers, which involved architects, interior designers, suppliers, and biosafety experts. Government executives and hospital administrations also assisted in the realization of the project. The portability of the design also allowed for cheap fabrication and easy assembly. The units that were deployed can also be reused for other purposes, such as guard houses, display booths, and the like.

Designing the Virus Trap

The Virus Trap was also developed to be used to isolate patients and suspected infected patients. Originating from an international design competition that seeks to gather ideas all over the world on how to combat COVID-19 infection using readily available materials, the Virus Trap is designed to be installed outside the door of any room, preferably a bedroom with its toilet and bath, to serve as a barrier to “trap” the virus from getting into other areas of the house. Using simple tools, anyone with a copy of the design blueprint can make one. The design allows the caregiver to put the supplies needed by the isolated person inside the trap while the door is closed, and the isolated individual can only access the trap by opening the door when the trap is zipped closed. This prevents the short circuit of the pressure near the door of the isolated person. It is assumed that the room is negatively pressured for the design to work. The trap must be disinfected every time.

Since the Virus Trap is easy to fabricate and install, one of the researchers was able to use one to isolate his son when he was exposed to a COVID-19-positive client in his workplace. The trap proved to be effective as it was easy to fabricate and use. It was also comfortable

Figure 4. Virus trap for quarantined patients at home

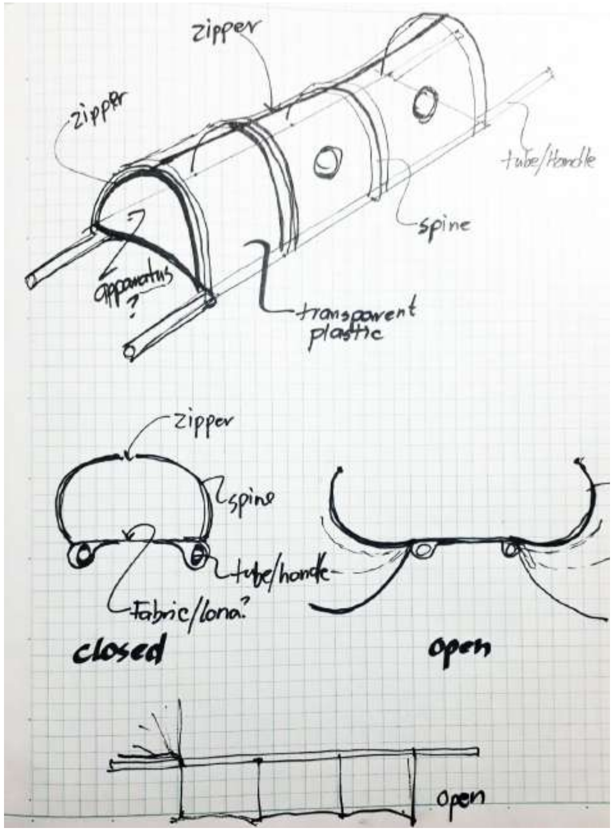
both to the isolated individual and to the caregiver. Although it has not been tested yet, the design is assumed effective based on the recommendations to put plastic barriers in all establishments.

Designing the Isolation Pod

After donating a unit of the PSCU to the Philippine General Hospital, there was a request from the doctors to design a transporter that would be able to protect the health workers from being infected while they transport them from their homes inside the ambulance. The idea is to be able to put the transporter, which we call the Isolation Pod, on top of stretchers. From a simple sketch and using cadaver grade polyolefin canvas, the pod is designed to be able to transport the patient from the home to the hospital or transport the patient from one hospital room to the next without having the health workers exposed even with minimal personnel protective equipment (PPE). Access to the patient to be able to put on oxygen, an IV, and other necessary tests should be integrated into the pod. It also has a USB-powered hepa13 filter with an air exchange of 80 cfm and a small exhaust fan to suck air from outside with a dual hepa13 filter as well. These fans are located at both ends of the pod to circulate the air inside.

Figure 5. Isolation Pod for Cebu Doctor's University Hospital (left)

Figure 6. Isolation Pod for Cebu Doctor (below)



Other issues on isolation and health worker protection brought out the design of the Virus Trap and the Isolation Pods.

The isolation pods were distributed to the Philippine General Hospital and some district hospitals in Cebu through the Cebu College of Surgeons. About 20 pieces have been manufactured. In finalizing the design, several consultations with the doctors from PGH have been done and the Isolation Pods have been used effectively although no evaluation has been done yet in terms of its effect on the protection of health workers and emergency personnel as a result of using the pods.

IV. Drawings/Photos to Highlight

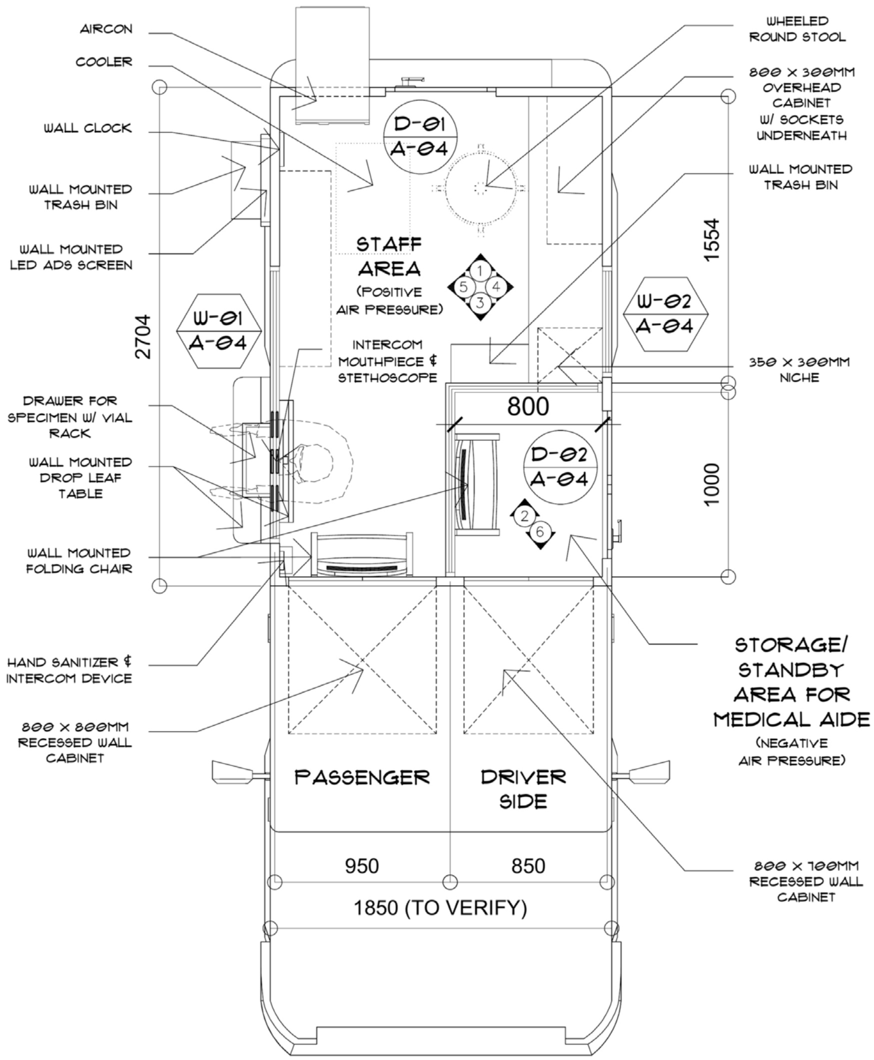


Figure 7. Floor Plan of the MSCU. Note that the passenger (medical aide), driver, and healthcare worker seats are all physically separated even inside the vehicle.

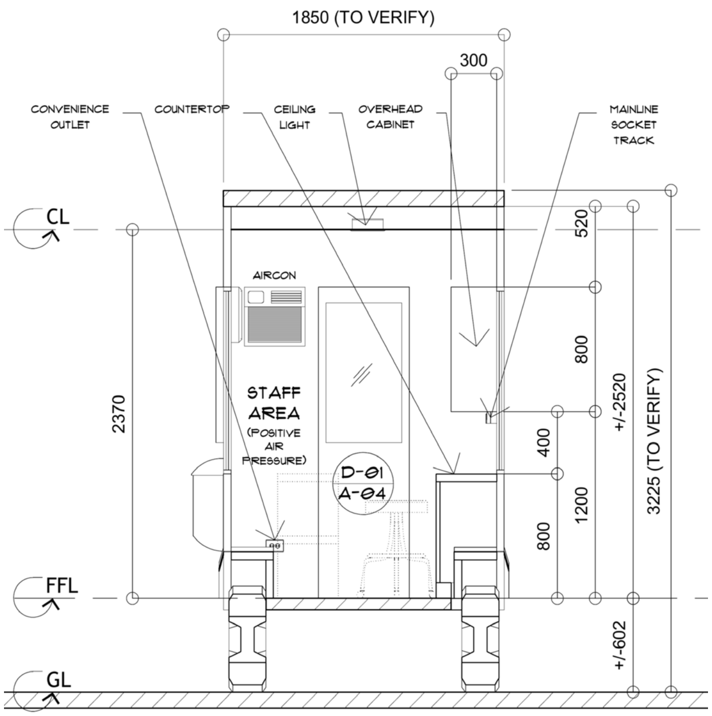


Figure 8. Section “1” of the MSCU based on the plan.

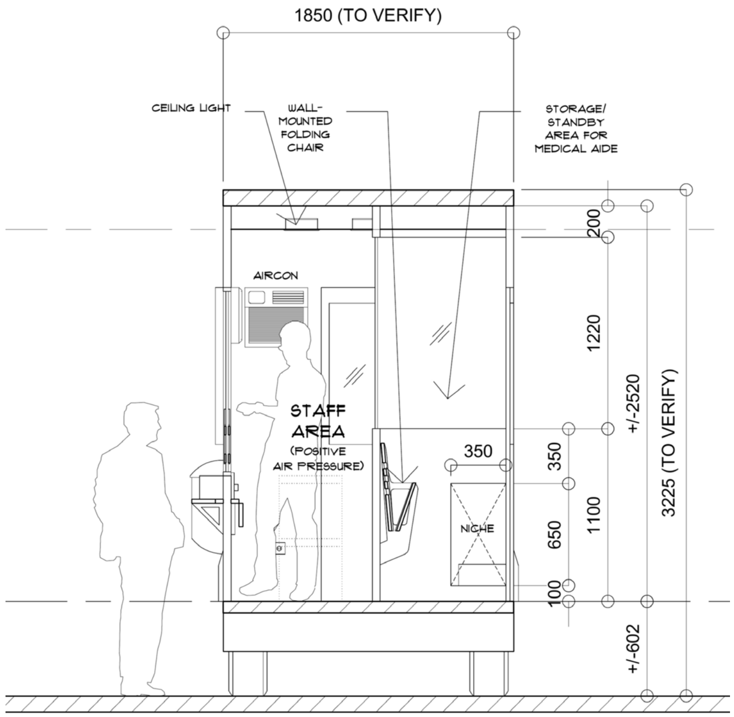
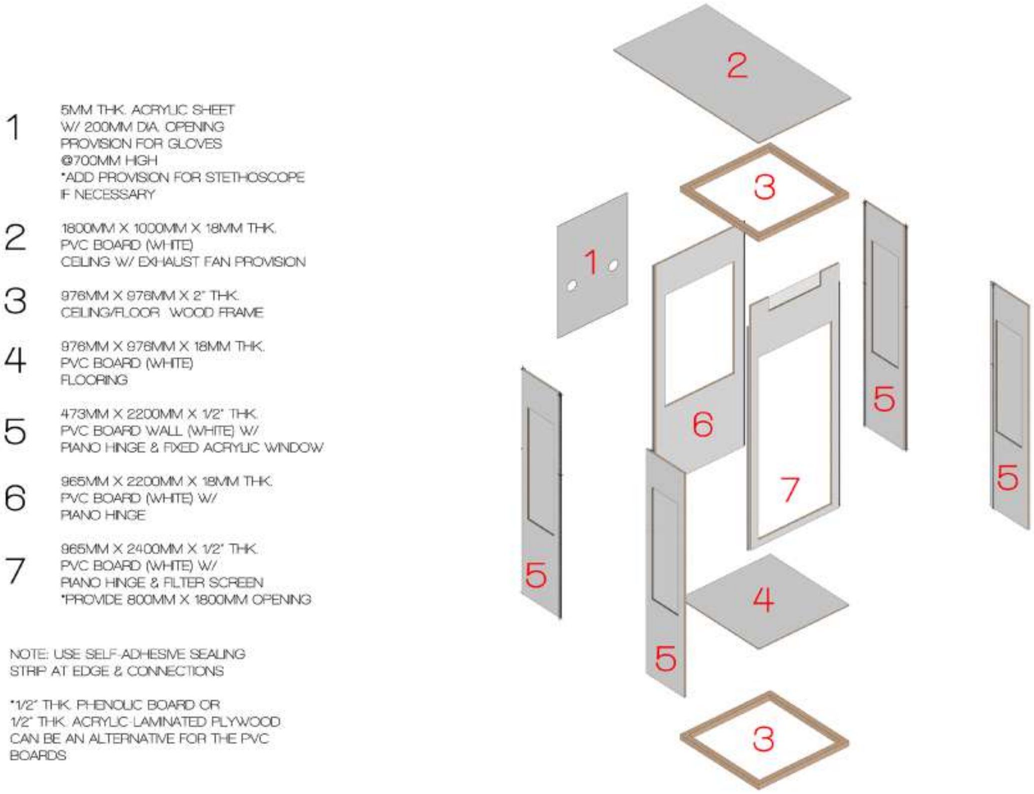
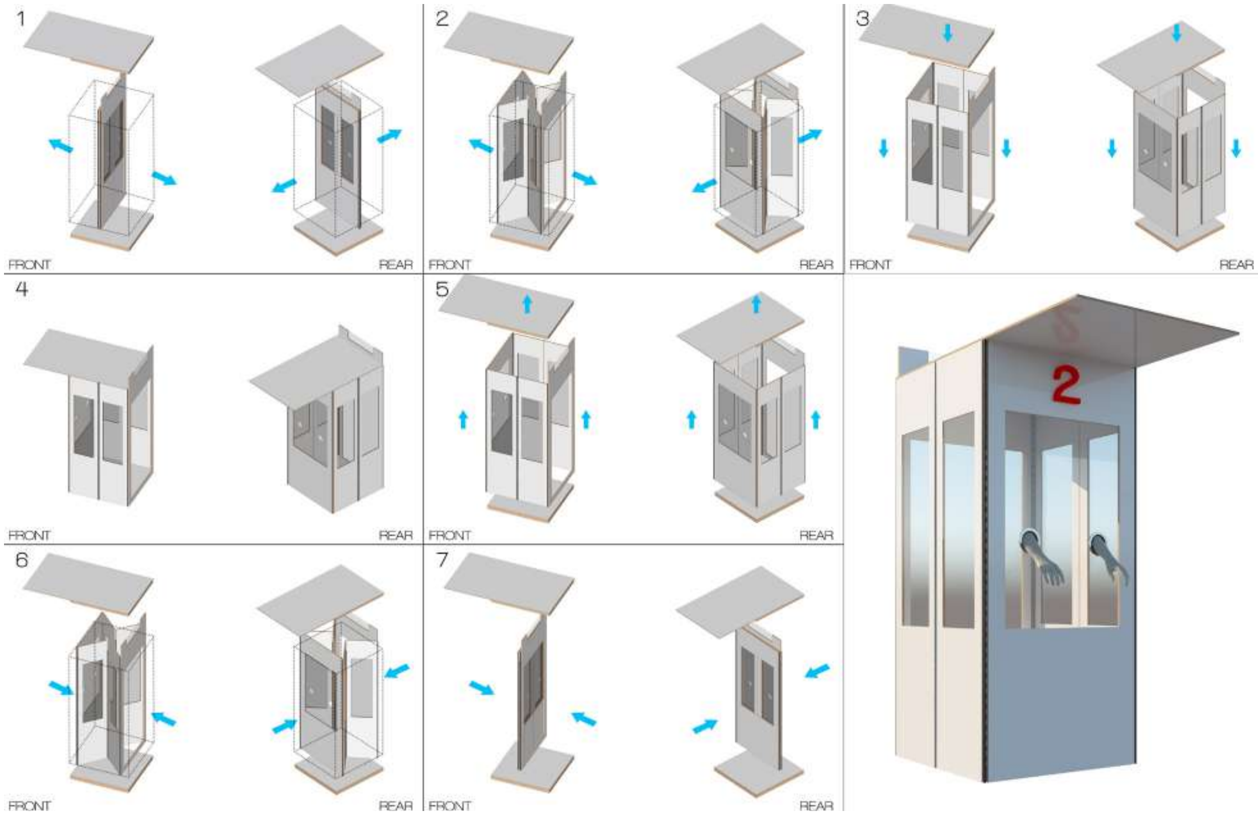


Figure 9. Section “2” of the MSCU based on the plan. In case of difficulty in testing due to discrepancies in height, a step ladder or a raised platform can be used to elevate the patients.



Figures 10-12. Putting together the PCSU (opposite page)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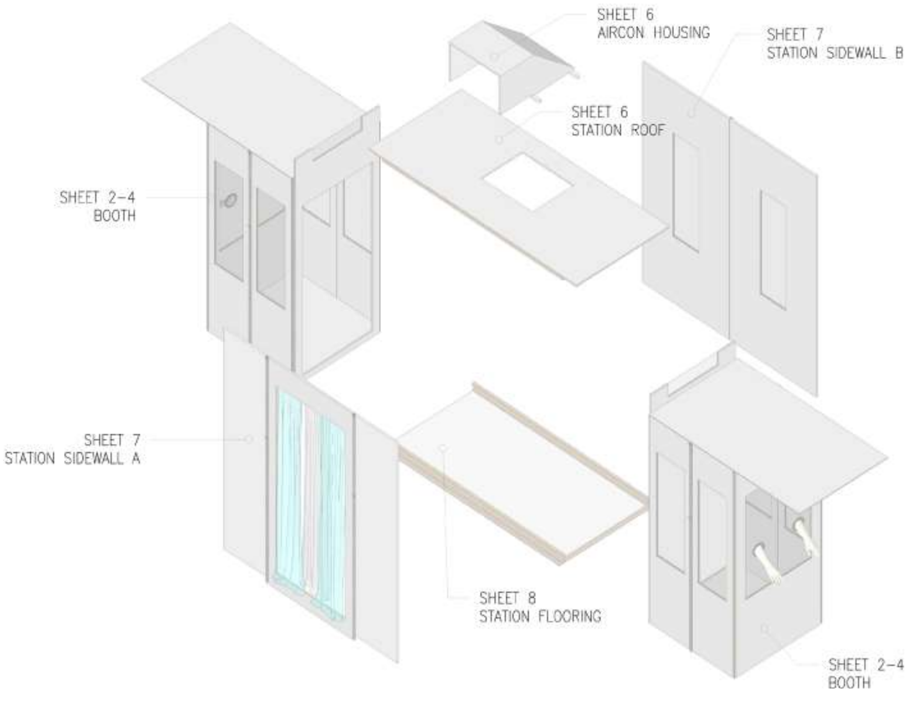
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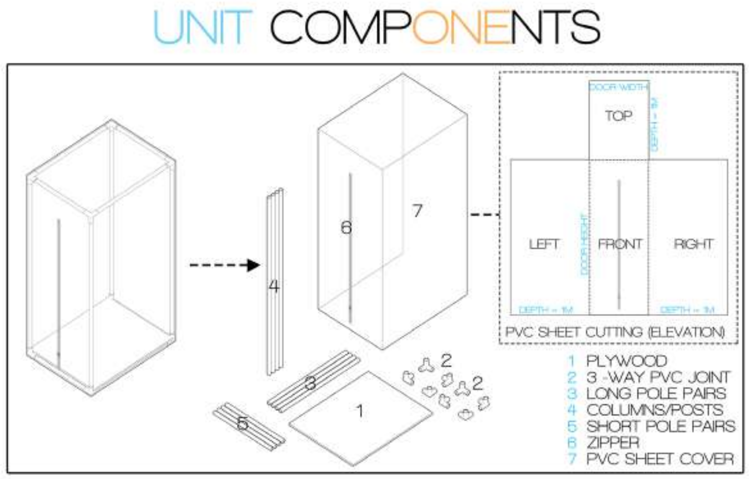
STATION SIDEWALL B
SHEET 6
STATION ROOF
SHEET 2-4
BOOTH
SHEET 7
STATION SIDEWALL A
SHEET 8
STATION FLOORING
SHEET 2-4
BOOTH

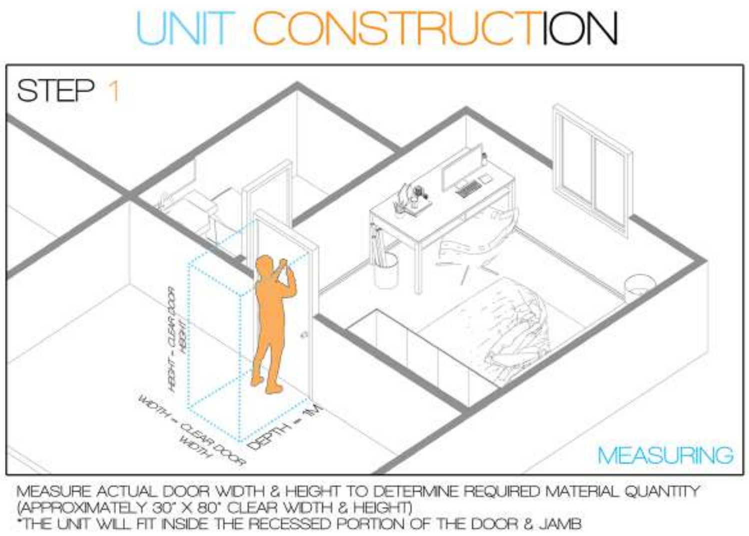
Figure 13. Suggested location of the PCSU (left)

Figure 14. PCSU installation at the Philippine General Hospital(below)

Figure 15. PCSU installation at the Lung Center of the Philippines (right)

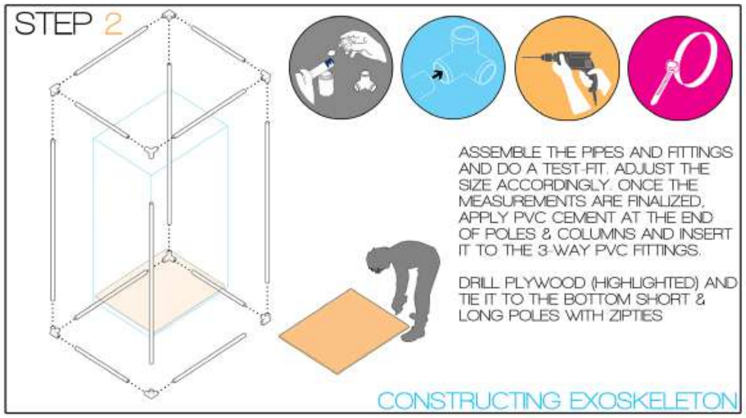
Figure 16. PCSU installation in Cavite (below)



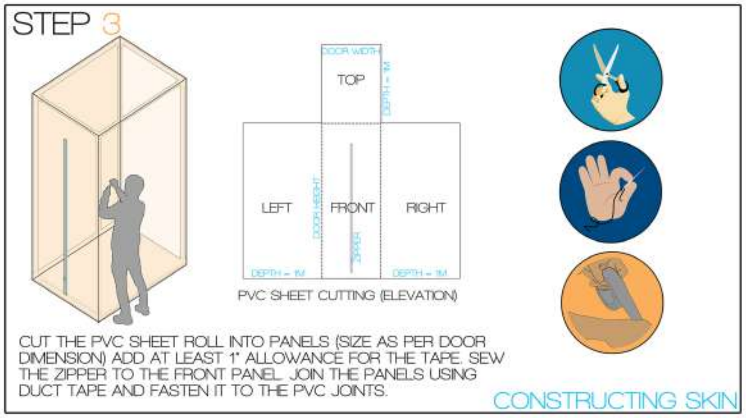


Figures 17-20. Putting together the Virus Trap

UNIT CONSTRUCTION

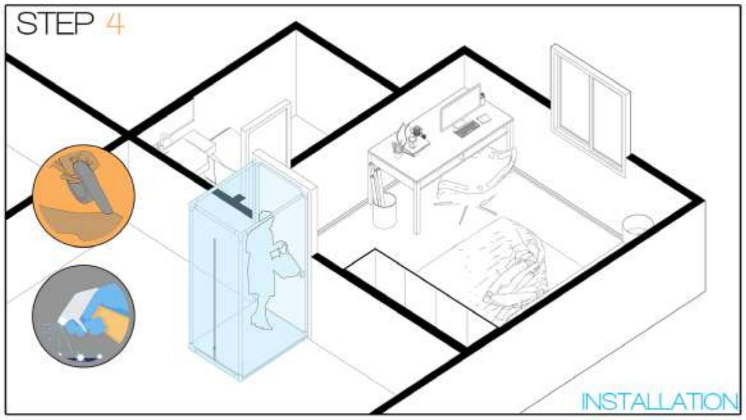


NOTE: MINIMUM OF 3 ZIPTIES PER SIDE TO MINIMIZE MOVEMENT OF THE PLYWOOD FLOORING.



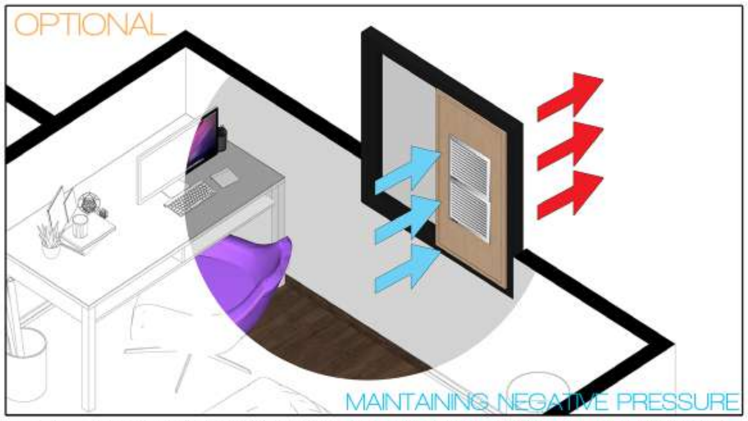
NOTE: SEAL THE STITCH LINE WITH DUCT TAPE & MAKE SURE TO AVOID ANY LEAKS

UNIT CONSTRUCTION



INSTALL THE UNIT IN THE PUI/PUM'S ROOM. SEAL ALL THE EDGES USING DUCT TAPE.

CONGRATULATIONS! YOU HAVE A VESTIBULE THAT MINIMIZES COVID TRANSMISSION. DON'T FORGET TO CLEAN AND DISINFECT THE VESTIBULE AFTER EVERY USE.



INSTALL WALL EXHAUST FAN WITH PLYWOOD FRAME IN WINDOWS TO HELP IN MAINTAINING NEGATIVE PRESSURE INSIDE THE PUI/PUM'S ROOM AND MINIMIZE VIRUS TRANSMISSION

Figure 21. Isolation Pod for the Philippine General Hospita (right)

Figure 22. IsolationPodforVicente Sotto Medical Center (below)

V. Conclusion

The pandemic has shown a key weakness in the healthcare system: lack of healthcare personnel. While this is a multi-dimensional issue that is too complex for this paper alone, the design presented allowed the designs to work with minimal healthcare workers. The MSCU only needed one healthcare worker, an aide, and a driver. While the PSCU only needed one person at the booth.

Meanwhile, the virus trap and the isolation pod are simple yet ingenious solutions to restrict virus infection on a more personal level, all while using readily available materials.

The designs presented in this paper also show the importance of portability and mobility during the pandemic, as transportation has been restricted.

The MSCU project would not have been possible without collaboration with other allied professionals such as doctors, biosafety officers, and car dealers. They provided the necessary design considerations and parameters when doing the MSCU. They ensured that the design complied with the operational requirements of swab testing. The project, which was done last April 2020, was also a preview of how virtual meetings would become the new normal in schools and offices. The whole project was conceived, planned, revised, and presented virtually without having any of the team members meet physically.

The project, especially the MSCU, highlighted the importance of institutional support in turning a design proposal into a reality. It was, regrettably, the greatest weakness in MSCU. Despite garnering media attention from outlets such as ANC[13], TV5[14], and Bluprint,[15] among others, the lack of support from key departments such as DOH and RITM would mean that the project would continue to become a proof of concept.

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