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Design Strategies for Biocontainment Units:

CREATING SAFER ENVIRONMENTS

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This white paper presents a summary of the work on the design of biocontainment units (BCU) that the SimTigrate Design Lab has been engaged in for the past 4 years. This document outlines design strategies for designing a safer and more efficient BCU, and is intended to provide information for designers (architects and interior designers), facility managers, and design researchers. These design strategies should be considered for implementation in both current and future BCUs.

INTRODUCTION

The SimTigrate Design Lab at the Georgia Institute of Technology has engaged in research on the design of biocontainment units (BCU) for several years, from the perspectives of both healthcare worker safety and patient experience. In response to increased awareness of the challenges of caring for patients with highly infectious diseases in the wake of the 2014 Ebola outbreak, Georgia Tech, together with Emory University and Georgia State University, took part in a multidisciplinary research program (Prevention Epicenter of Emory and Atlanta Consortium Hospitals – PEACH), funded by the Centers for Disease Control and Prevention (CDC). It focused on exploring new strategies to improve the safety of both patients and healthcare personnel during care delivery. The SimTigrate research team focused on ways in which the built environment might support or hinder safe doffing of personal protective equipment (PPE) within a BCU.

OVERALL DESIGN CONSIDERATIONS OF BCU

Ebola Virus Disease (EVD) spreads through human-to-human transmission via direct contact or contact with the bodily fluids of an infected person, and indirectly through contact with contaminated surfaces and materials (e.g., medical equipment) (World Health Organization 2018). Removal of PPE is recognized as a high-risk activity because the healthcare worker (HCW) needs to extract themselves from the potentially contaminated PPE without it coming into contact with their bare skin. This can be an especially difficult task to accomplish after providing hours of direct patient care, as healthcare

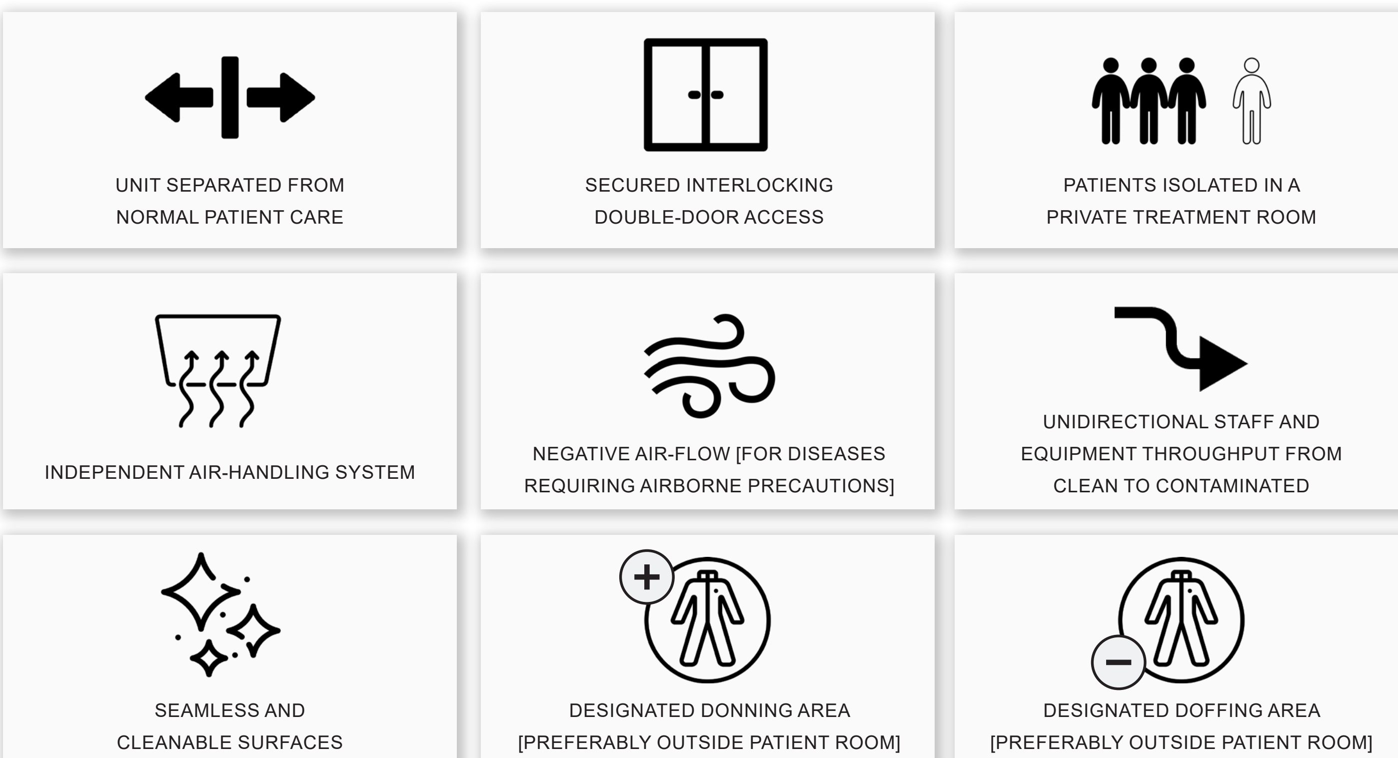

FIGURE 1. General design considerations for biocontainment units

workers are likely fatigued, which can contribute to errors or risky behaviors and potential acquisition of lethal pathogens (Casanova, Alfano-Sobsey et al. 2008, Tomas, Kundrapu et al. 2015, Casanova, Teal et al. 2016).

General design requirements specify that the BCU needs to be separated from normal patient care areas with secured interlocking double-door access, have an independent air-handling system and negative air-flow, seamless and cleanable surfaces, and a pass-through autoclave (Smith, Anderson et al. 2006). In response to the 2014 Ebola outbreak, the CDC updated their guidance on PPE (including procedures for PPE donning and doffing) in which they emphasized the importance of BCU design, highlighting the need for a separate, dedicated space for doffing in order to reduce the risk of cross- and self-contamination of healthcare personnel (Centers for Disease Control and Prevention 2014). The CDC guidelines suggest that the donning and doffing areas need to be separated from the direct patient care area (patient's room), and the layout should allow for clear separation between clean and contaminated areas. A unidirectional staff and equipment throughput that follows a clean-to-dirty path should be clearly marked with visible signage (e.g., color demarcation on the floor). The doffing area should be large enough to enable freedom of movement of HCWs during doffing and to accommodate all necessary equipment. Additionally, all steps of PPE donning and, especially, doffing need to be visibly monitored by a Trained Observer (TO) (Centers for Disease Control and Prevention 2014).

SPECIAL DESIGN REQUIREMENTS FOR THE DOFFING AREA

Over the course of multiple projects, the SimTigrate Design Lab team has learned how the design of the biocontainment unit, and in particular the layout of the doffing area, can reduce the contamination risk of HCWs. We identified 5 key design requirements of doffing spaces that support safer HCW behavior during the doffing process:

(1) Facilitate communication between HCW and TO;
(2) Signify steps in the PPE doffing process;
(3) Provide stabilization for the HCW during PPE doffing;
(4) Nudge/automate the safest choices; and
(5) Promote situational awareness (DuBose, Matić et al. 2018, Zimring, Matić et al. 2018).

In a redesigned doffing area, with some of these strategies implemented, we found that both physical and cognitive load of HCWs, as well as the occurrence of risky behaviors, significantly decreased (Wong, Matić et al. 2019). Our studies have demonstrated that optimized design and layouts that are based on ergonomic principles and empirical guidelines can have a measurable impact on HCW contamination risk while doffing their PPE (Wong, Matić et al. 2019).

For more details on methods and design recommendations, please see our recent publications:

DuBose, J. R., Z. Matić, M. F. W. Sala, J. M. Mumma, C. S. Kraft, L. M. Casanova, K. Erukunuakpor, F. T. Durso, V. L. Walsh, P. Shah, C. M. Zimring and J. T. Jacob (2018). Design Strategies to Improve Healthcare Worker Safety in Biocontainment Units: Learning from Ebola Preparedness. *Infection Control & Hospital Epidemiology,* 1-7.

Zimring, C. M., Z. Matić, M. F. W. Sala, J. M. Mumma, C. S. Kraft, L. M. Casanova, K. Erukunuakpor, F. T. Durso, V. L. Walsh, P. Shah, J. T. Jacob and J. R. DuBose (2018). Making the Invisible Visible: Why Does Design Matter for Safe Doffing of Personal Protection Equipment? *Infection Control & Hospital Epidemiology,* 39(11): 1375-1377.

Wong, M. F., Z. Matić, G. C. Campiglia, C. M. Zimring, J. M. Mumma, C. S. Kraft, L. M. Casanova, F. T. Durso, V. L. Walsh, P. Y. Shah, A. L. Shane, J. T. Jacob and J. R. DuBose (2019). Design Strategies for Biocontainment Units to Reduce Risk During Doffing of High-level Personal Protective Equipment *Clinical infectious diseases,* 69(Supplement_3): S241-S247.

OPTIMIZED LAYOUT OF DOFFING ROOM FOR SINGLE- AND DUAL-USE

Doffing area detail shown on next page (Figure 3.)

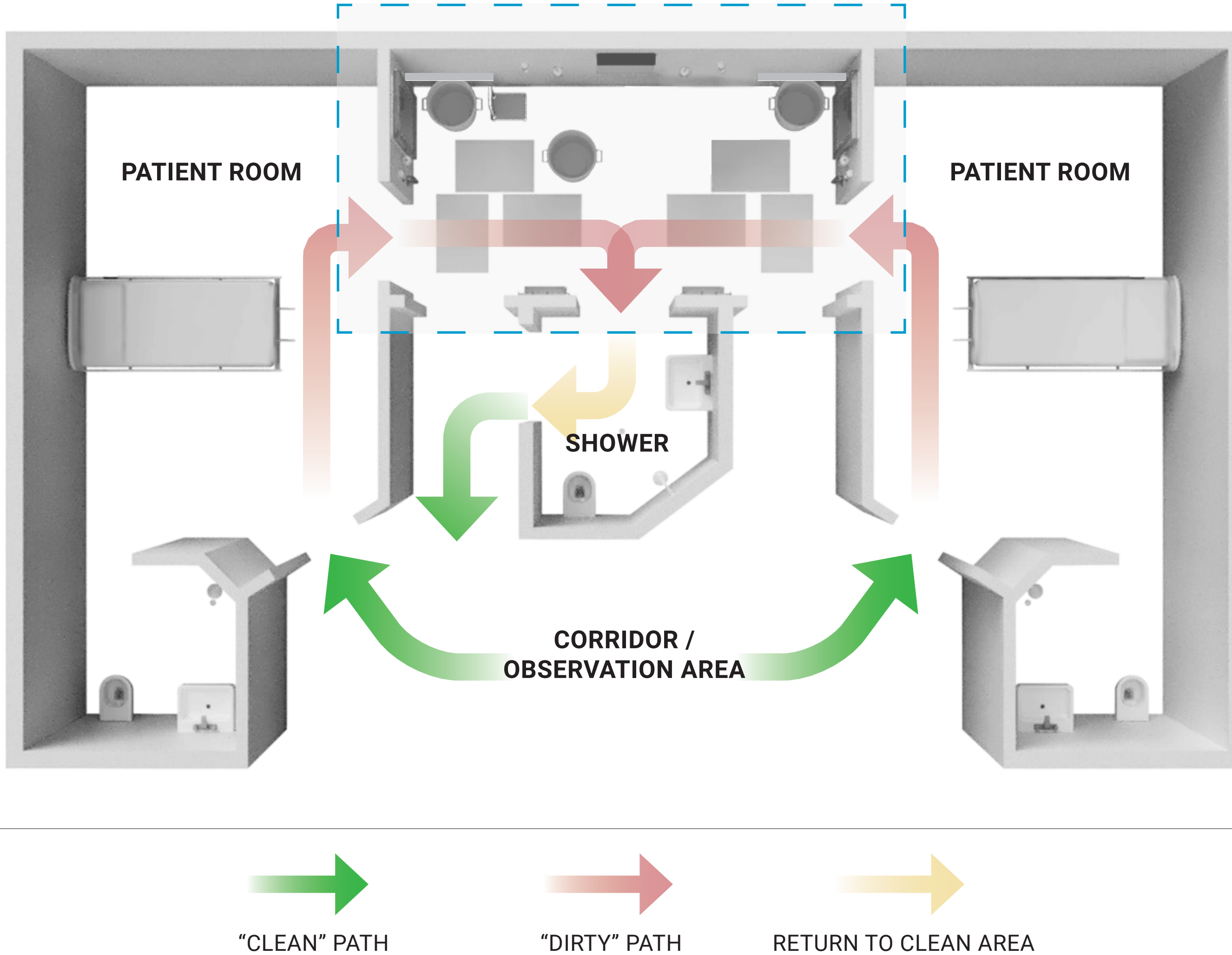

FIGURE 2. The overall layout of the biocontainment unit, showing treatment rooms, doffing area, shower, and observation area. The layout allows for unidirectional staff and equipment flow that follows a clean-to-dirty path.

We propose the following optimized design for a biocontainment unit based on our evaluation and testing of many BCU designs. The proposed unit consists of two patient rooms, connected by a large doffing area in the middle. Each patient room has an exterior window, a window to the doffing area, and a window to the corridor that, in addition to the built-in communication system, allows for patient observation, staff communication, and communication between family members and the isolated patient (Figure 3).

The unit enables unidirectional flow, with a path that allows HCWs to move from clean to dirty areas without backtracking. This layout can support either one or two patient rooms. Having one doffing area that serves two patient rooms is an efficient way to use space and can reduce the staffing burden for Trained Observers, as one TO can doff both HCWs entering from the room on the left and the room on the right (with their doffing times staggered, ideally in 2 hour intervals, instead of simultaneously). The dashed line shows the location of a wall should the doffing area be built to only support a single room.

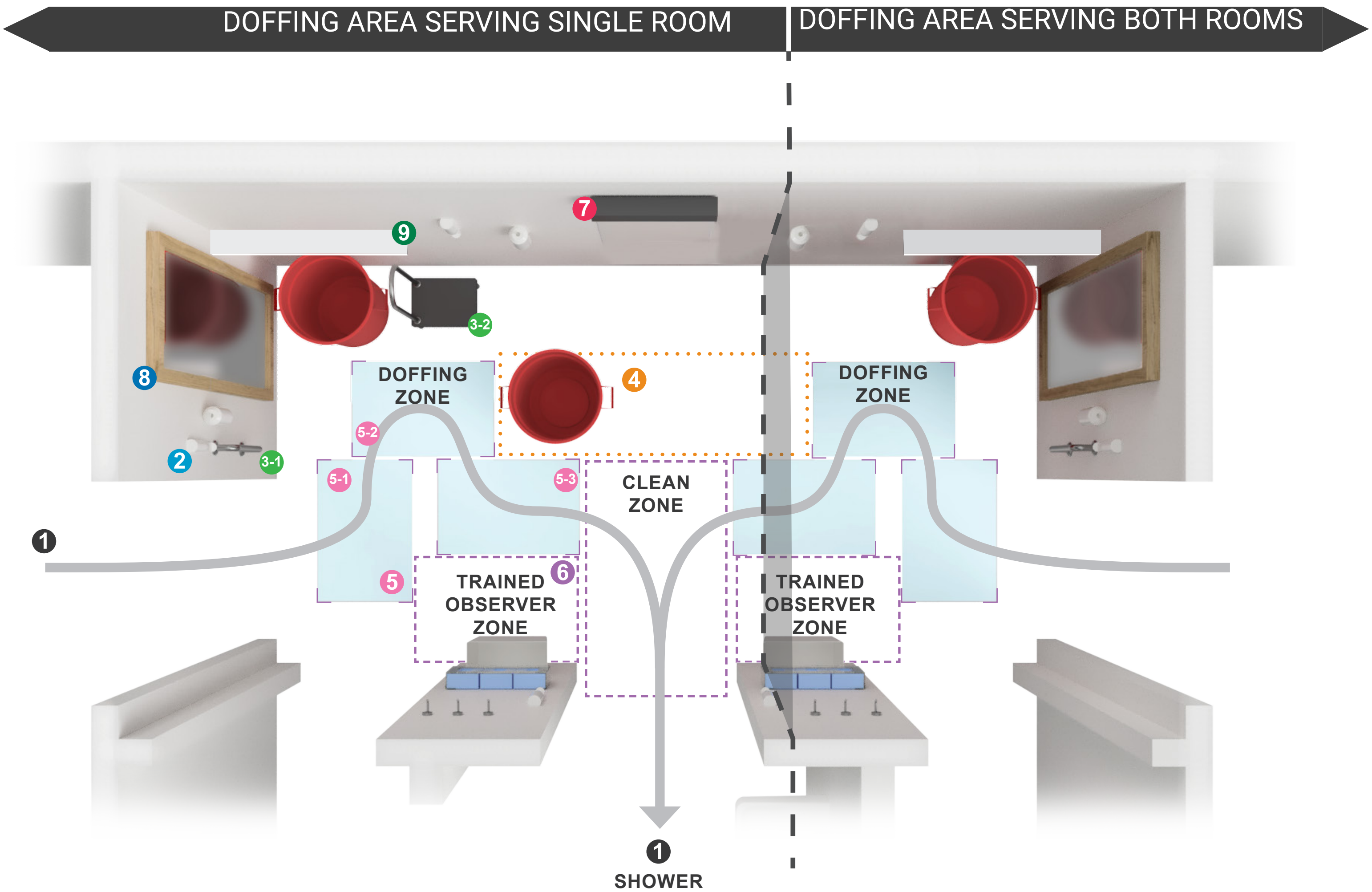

FIGURE 3. The layout of the doffing area with all necessary equipment

1. The designated path follows a **unidirectional flow** for HCW during entire doffing process

2. HCW has **quick and easy access to wall-mounted hand hygiene** (wipes and hand sanitizer) at all times and locations. Wall-mounted hand hygiene should be within reach of HCW (recommended distance 20.5")

3. HCW has **quick and easy access to balance aids**. Primary means should be fixed (e.g. wall-mounted grab bar 3-1), and secondary means should be mobile (e.g. 3-2 L-shaped stool)

4. Designated area for primary-use trashcan offers **flexibility** to accommodate **various reach envelopes**

5. Chemical mats (5-1; 5-2; 5-3) for HCW to step onto while doffing. **TO automates as much of the doffing process** as possible by setting up space (e.g. establishing chemical mats) to reduce the cognitive burden of HCW

6. **Floor is demarcated** to signify HCW path and direction to shower, area for TO observation, and placement of equipment (e.g. chemical mats)

7. TO has unobstructed visibility of a wall-mounted **doffing protocol and digital clock** for timing duration of hand hygiene

8. HCW has unobstructed **visual access to a mirror for self-inspection** from the designated doffing zone

9. **Shelves and storage options** should not obstruct the processes of doffing and cleaning, yet should be immediately accessible

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