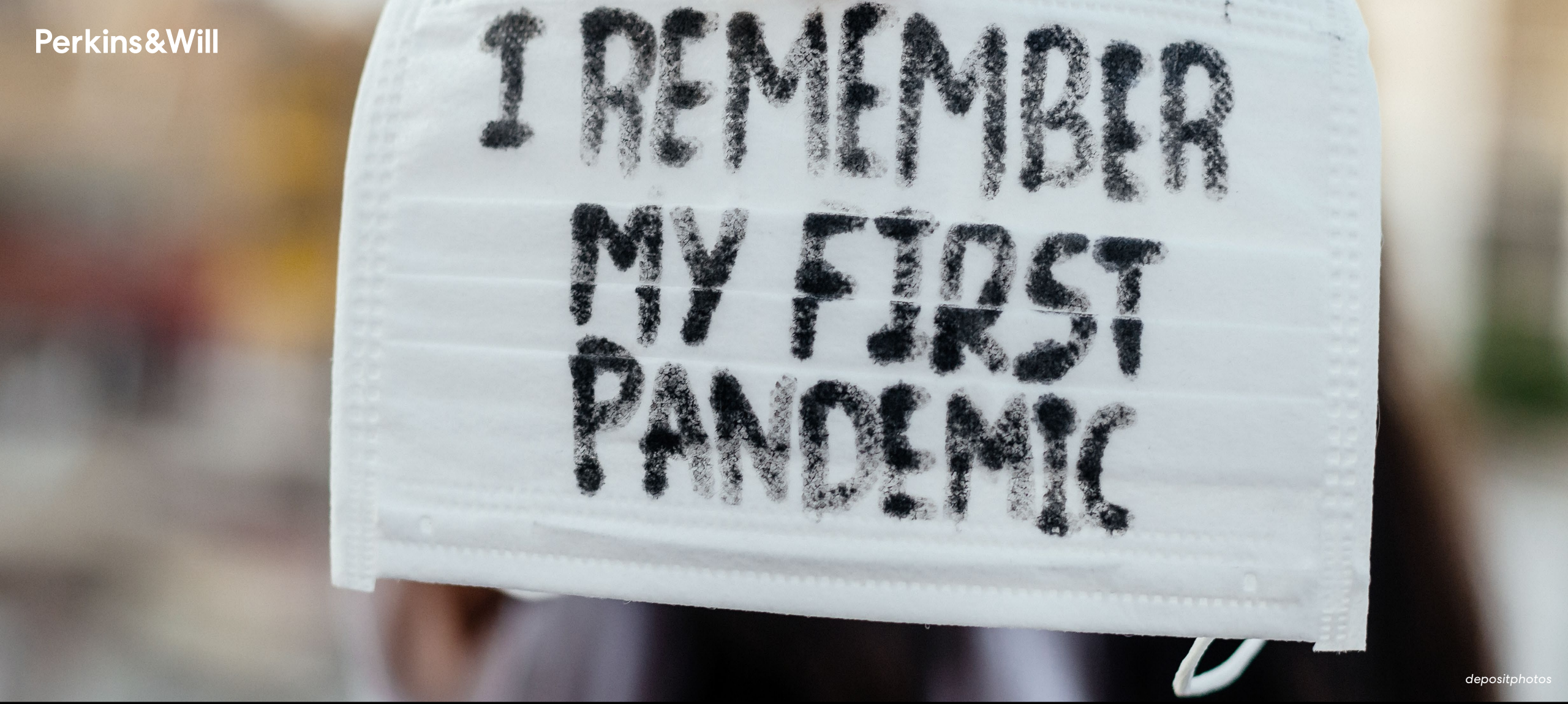
Perkins&Will



depositphotos

Infectious Pandemic Surge ICU Unit Program

Written By: Susan Ealer

Introduction

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ICU Unit

ICU Room

Hospital

Space Program

Introduction

‘Stay Safe’ - the new salutation.

depositphotos

Introduction

Testimonial:

"I don't want to go to the hospital because I'm going to die there." That's what I told my husband as I lay on my side next to the humidifier trying to breathe with my heart racing. It was late March 2020 and the pandemic had just bloomed in New York City. I had continued walking blithely through the streets without a mask because masks were deemed "ineffective." I called my doctor for an asthma inhaler refill and hung up with a clinically diagnosed case of COVID-19 and an order to stay in my room. So, to say I "told" my husband I was terrified to go to the hospital probably meant I texted him or shouted it at him through the door.

At the height of the surge, The New York Times was my window to the world. I was pulling it up every couple of hours on my phone and the news was frightening. City-wide, 3,500 ICU beds were filled with COVID patients. People being treated in world-class institutions were dying on ventilators. 800 deaths were reported in a single day and morgue trailers were overflowing. The irony that these live-saving institutions had become places to fear and avoid in an emergency is obvious to anyone. To a person who plans hospitals for a living, it was especially disconcerting."

– Author, COVID-19 patient

"I don't want to go to the hospital because I'm going to die there..."

- Author, COVID-19 patient

Introduction

Infectious Pandemic Surge Program - ICU

I am writing this paper to outline an Infectious Pandemic Surge Space and Functional Program for the ICU in response to the great need for Critical Care Pandemic Preparedness that I witnessed every day during the spring 2020 COVID-19 surge here in New York City. The lack of proper facilities and resources to respond to this crisis was something I personally experienced, first as a patient, then as a member of the GYNHA COVID-19 Task Force. As a Medical Planner and Programmer, this is my way of giving back to the physicians, nurses, and other front-line workers who saved our lives.

The first step in planning is to define the need. This might seem simple and obvious but in fact, this task is exceedingly difficult. I would argue that this is the most difficult task in planning. The first part of this investigation seeks to define the parameters for an Infectious Pandemic Surge Space and Functional Program for an Intensive Care Unit - something practical and evidence based that clients and designers can learn from, can afford, and can implement.

The second step is to develop and communicate the Planning Strategy. When trying to plan for a complex, clinical response to a rapidly spreading pandemic caused (in the case of COVID-19) by an unfamiliar pathogen, this task becomes exponentially more difficult. Not only is this paper based on hours of research gathered from official guidelines, task force recommendations, scientific reports, and the work of other people trying to answer the same questions, it is shaped by a series of interviews I conducted with front-line providers, experts, patients, and Perkins&Will healthcare leaders. This is their paper as much as it is mine and I am very grateful for their time and for their contributions.

It is my hope that this paper provides helpful, practical recommendations, informed by expert experience and clinical practice. **I have focused the study on the simplest module – a 12-Bed ICU Unit and, by extension, some of the pieces that link to the unit.** These include the patient room, and elements of the hospital as a whole: patient circulation, waiting rooms, etc.

"I recently did a carpentry job for a new client, a nurse. Turns out she was the nurse who took care of my friend when he was dying in the hospital (of COVID-19)..."

- Friend of COVID-19 patient

Introduction

Program Format

The recommendations outlined in this document are presented in the form of a Functional Program, which includes prescriptive recommendations and diagrams, and a Space Program, which lists all required functions by category and outlines their size in terms of square footage. The development of the Space and Functional Programs followed a traditional Medical Planning User Group Process.

Step 1: Interview the users (the people who are going to use the end-product) to determine their needs.

Step 2: Interview experts and leaders in the field for best practices and recommendations.

Step 3: Develop solutions which address needs and incorporate the most innovative thinking available in the industry.

Step 4: Vet the solutions with the users and experts involved. In this case, vetting involved follow-up conversations and reviews of the draft report.

Additionally, included in the Functional Program are the following: Case Studies, Contributor Wish Lists, excerpts from interviews (see below), and expert input on specialized topics (i.e., logistics, mechanical systems, technology, equipment).

Interview Format

The interviews followed a documentary-style format which is designed to be spontaneous, investigative, and exploratory. Interviews were based on a framework of standard questions but were structured to allow the conversation to take its course based on the interview subject's answers and expertise.

"I'm nervous about the winter. The numbers are going to go up. "

- Nurse treating COVID-19 patients

Introduction

Interview Questions

The questions were designed to capture the following:

- The subject's recent personal experiences coping with the COVID-19 Pandemic
- Lessons learned during the recent COVID-19 Pandemic with regards to patient/staff wellbeing, operational procedures, infection control and surge capacity
- Recommendations for adapting ICU design and overall pertinent hospital support infrastructure to respond to a future infectious pandemic.

Some Standard Questions

- What crucial lessons did you learn about clinical practice, operations, and space needs during the recent COVID-19 Pandemic? What worked and what did not work?
- Separation of infectious patients from the rest of the population within a hospital is key. This includes getting them to the unit(s) and allowing them to access diagnostic and treatment facilities that cannot be brought to the bedside. What tactics do you see as being successful in this regard?
- What are the biggest challenges in terms of supplies and equipment in situations like these?
- What do you think are the most important functions/elements that should be provided in a 12-Bed Infectious Pandemic Surge ICU Unit? In an ICU patient room?
- What is on your wish list going forward?

"During a pandemic like this, one of the most helpful things leadership can say is that we don't know what's going on but we're using every resource available to influence the decisions we're making and adapting those based on feedback. "

- Department Director, Major New York Hospital

Contributors

Maxim Tochinski Unsplash

Front-Line Workers

Physicians treating COVID-19 patients

Nurses treating COVID-19 patients

Hospital Department**Directors**

Adam Niescioruk Unsplash

Patients

COVID-19 **Patients**

Friends of COVID-19 patients

Shahadat Rahma Unsplash

Experts

Phil Crompton, Principal, Vantage Technology Consulting Group

Lynne Ingle, RN, former OR Manager, Senior Director Medical Equipment Planning MERC/HLW

Sean O'Neil, Executive Vice President, St. Onge Company

Perkins&Will

Perkins&Will Healthcare Leaders

Jeffrey Dreesman, Healthcare Practice Leader Western Region

Chisako Fukase, Medical Planner

Anthony Mistretta, RN, MS, Healthcare Ops + Strategic Planning Executive

Chuck Siconolfi, Regional Director, Principal

Marvina Williams, RN, BSN, former ED Director, Senior Medical Planner, Associate Principal

Infectious Pandemic Surge

COVID parade, Torrevieja, Spain.

Infectious Pandemic Surge

Insight:

You don't need a large trigger to set off a large event...imagine a drop of water falling onto a high, knife-edge mountain, If it falls on one side of the ridge, to will flow away...to a deep ocean, if it falls on the other side of the ridge, it will flow into another deep ocean...the two trajectories leading to such different final states may start out infinitesimally close together.

- John Gribbon, Deep Simplicity

Infectious Pandemic - What to Prepare For Next

Recent large scale infectious events have included such disparate pathogens as HIV/AIDS, Ebola, those generated by the threat of bioterrorism, and COVID-19. Designing a 12-Bed ICU that has the capacity and flexibility to handle a wide variety of potential pathogens, with special emphasis on the most likely pathogens, is the strategy advocated by this program.

It's chilling to read the 2017 Johns Hopkins Bloomberg School of Public Health Center for Health Security's paper, *The Characteristics of Pandemic Pathogens*, on the heels of New York City's spring 2020 COVID-19 Pandemic Surge. The Novel Coronavirus checks all the boxes for a **GCBR-Level Pandemic Pathogen**. GCBR's are microorganisms (natural or created) that constitute a Global Catastrophic Biological Risk.

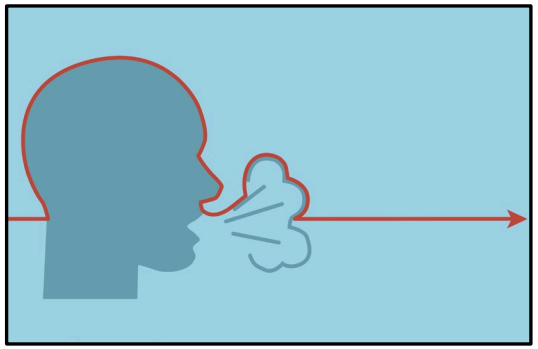
As seen most recently with COVID-19, GCBR's can lead to sudden, extraordinary, widespread disaster beyond the collective capacity of national and international governments and the private sector to control. GCBR's have the capacity to cause great suffering, loss of life, and sustained damage to political and economic infrastructures.

"We went through outbreaks of Ebola and the Measles but we never prepared for anything like this."

- ER Physician on the COVID Pandemic

Infectious Pandemic Surge

The Most Likely Candidates for The Next Pandemic



UN, Unsplash

Respiratory Transmission
(Including During Incubation)

Influenza A (H7H9)
Parainfluenza (HPIV)
Coronavirus/SARS
Respiratory Syncytial Virus (RSV)
Enterovirus
Rhinovirus

Jenny Pace, Unsplash

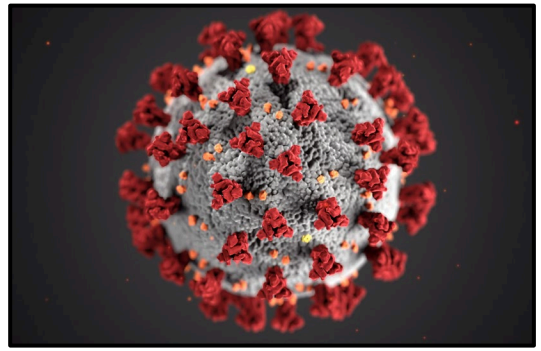
RNA vs. DNA
(Less Stable/More Mutation)

Influenza A (H7H9)
Parainfluenza (HPIV)
Coronavirus/SARS
Respiratory Syncytial Virus (RSV)
Enterovirus
Rhinovirus

Mykenzie Johnson, Unsplash

Absence of Cure

Influenza A (H7H9)
Parainfluenza (HPIV)
Coronavirus/SARS
Respiratory Syncytial Virus (RSV)
Enterovirus
Rhinovirus



CDC, Unsplash

Appreciably Fatal

Influenza A (H7H9)
Parainfluenza (HPIV)
Coronavirus/SARS
Respiratory Syncytial Virus (RSV)
Enterovirus
Rhinovirus

Infectious Pandemic Surge

In determining which organisms are likely candidates for GCBR's, it is important not to rely on "historical pathogen list-based approaches," such as creating a list of the "10 worst pandemics of all time." One of the key criteria for a virulent GCBR is that there is no known cure. This would rule out something like the Bubonic Plague, which can now be cured with antibiotics, or even Malaria, which is hypothesized to have killed half of all humans who have ever lived over time.

Surge

Surge is defined as a sudden, unanticipated escalation in health system demand caused by exceptional events.2 Surge events affect critical care in a variety of ways depending on the onset, impact, and duration of the incident. Sudden impact events tend to affect Emergency Department services more acutely but the impact to critical care and Surgical Services can last for days or even weeks afterward. Slow-onset disasters, like hurricanes or pandemics, pose the challenge of maintaining a sustained critical care response over weeks and months – sometimes even years. These events tend to have more impact on the ICUs as patients are transferred from the Emergency Department and may need ongoing care for an extended period of time.

"What is the next thing that's going to come around? First there was 9-11 with bio-terrorism, then there was Ebola, now COVID?"

– Marvina Williams

Surge *- a sudden, unanticipated escalation in health system demand caused by exceptional events.*

Edwin Hopper, Unsplash

Case Study: Infectious Pandemic Surge
New York City, COVID-19

Overwhelming Loss Of Life:

Estimates put the number of pre-COVID ICU Beds in New York City at 1600. As of June 28, 2020, the City had 212,000 confirmed cases of COVID-19 and nearly 55,000 patients had been hospitalized. A substantial percentage of these patients required critical care (approx. 5000 admitted at peak). Lower-income communities were especially afflicted.

As a GCBR-Level Pandemic Pathogen, COVID-19 spread quickly through respiratory transmission during its incubation period in a population with no immunity. Front-line physicians and hospital staff, who had never encountered anything like this before, took heroic measures but were unable to stem the tide of patients dying in their care.

Shortages of Staff/Supplies:

"Hospital leaders estimated that about a third of doctors and nurses were out sick. The hospital temporarily ran out of protective plastic gowns, the main sedative for patients on ventilators, of a key blood pressure medication. The sense of urgency and tragedy was heightened by a video circulating online, showing a forklift hoisting a body into a refrigerated trailer outside the hospital." - Sheri Fink, Code Blue

Equipment/Infrastructure Failures:

Critically ill patients' need for dialysis and for ventilators far exceeded the hospitals' baseline capacities and the available supply chain inventory. Oxygen tanks were strained or malfunctioning. One private hospital in the City had to be partially evacuated as its oxygen supply broke down.

Richard Goff, Unsplash

Planning For Chaos

'The Universe operates in an irreversible way. You can never put things back the way they used to be.'

- John Gribbon, Deep Simplicity

Planning For Chaos

Insight:

With a pandemic, you have no idea what your volumes will be. New York Presbyterian, a 1200 bed hospital, was 100% COVID ICU at one point. The current pandemic is particularly scary because we are living through a scientific development - COVID-19 is a six-month old virus that is still in its early infancy. This is exactly what happened with Smallpox and the Flu of 1918. There is no cookie-cutter response to pandemics like these. All we can do is to try to be socially responsible, continue to educate ourselves – bringing the best, newest information forward – and maintain flexibility in our response.

- Anthony Mistretta

Chaos Planning

In the face of an Infectious Pandemic Surge, how do you plan for the chaos? The type of pandemic, its magnitude, and where and when it will occur are all unpredictable. Pandemics can draw down local and global resources in complex and unexpected ways.

Experts in chaos theory, however, point out that chaos and order are inextricably intertwined. *"In the midst of order, there is chaos but in the midst of chaos, there is order." – John Gribbon, Deep simplicity.* Planners can leverage this order to incorporate preparedness into their space and functional programs.

Luckily, chaos isn't all just chaos and we can take some measures to be prepared for an infectious pandemic surge.

"No strategist in a million years could have predicted that New York City would be crippled to the point of needing tents in Central Park because every ICU bed was filled with COVID patients."

- Anthony Mistretta

Planning For Chaos

With a pandemic, patient volumes are inherently unpredictable. In the spring of 2020, the patients being treated at New York Presbyterian, a 1200 bed hospital, were 100% COVID-19 ICU acuity level patients at one point. The existing framework for surge response to pandemics such as these is a continuum with thresholds that distinguish conventional surge from contingency surge and crisis surge.9, 10 The continuum is recognized by such organizations at the World Health organization (WHO) and the Centers for Disease Control and Prevention (CDC).

- Conventional surge response targets are generally achieved using available resources.
- A contingency surge response usually requires critical care to be provided in non-traditional hospital areas (such as Post Anesthesia Care Units) and must incorporate community or regional resources.
- A crisis surge response, like the one seen in New York City during March through June, in 2020, forces a portion of critical care outside the hospital setting into temporary alternate care sites and relies on national stockpiles and networks of resources.

Guiding Principles

The overall ICU planning guidelines presented here draw from chaos planning protocols and infectious pandemic surge response recommendations, from lessons learned during case studies and user interviews, and from design industry standards and best practices. These guidelines form the **Guiding Principles** that shape the planning recommendations outlined in this article.

"Chaos is completely orderly and deterministic…it is just that it is impossible to predict in detail what is going to happen more quickly than events unfold in real time."

– John Gribbon, Deep Simplicity

Case Study: Planning For Chaos
New York City, COVID-19

Rapid Expansion of Capacity:

"As the number of cases rose in the city, NYC Hospitals carried out plans to greatly expand critical care capacity. At baseline one NYC Hospital had an ICU capacity of around 300 beds. At the peak of the COVID-19 surge, the network was caring for 1,000 ICU patients. Another hospital in the Bronx increased from its baseline ICU capacity of 34 up to a capacity of 195." – Health Affairs, Critical Care and ED Response at The Epicenter of the COVID-19 Pandemic

- Primary Intensive care unit (ICU) spaces were identified and upgraded as needed
- New ICU spaces were created in emergency departments and other inpatient units.
- Procedural areas such as endoscopy suites, perioperative suites, post-anesthesia care units, and operating rooms were identified as flex ICU spaces because elective procedures were being deferred.
- Patients were also transferred between hospitals to reduce strain.

Creative Logistics:

The current operational just-in-time approach, where hospitals rely on daily deliveries, failed during the New York City COVID-19 surge and creative logistical methods were employed to provide life-giving items like ventilators and PPE.

"Passenger aircrafts were put into freight service, production lines were converted over to produces needed medical products, and communities banded together to hand produce masks and other products. " – Sean O'Neil

Surge Response Continuum

	Conventional	Contingency	Crisis
Space	patient care space maximized	additional patient care areas re-purposed	non-traditional areas used for critical care
Staff	additional staff as needed	additional patients/ responsibilities	insufficient ICU trained staff available
Supplies	cached/on-hand supplies	conservation, adaptation, and substitution of supplies	critical supplies lacking
Standard of Care	usual care	minimal impact on usual care	not consistent with usual standard of care
ICU Expansion Goal	x 1.2 usual capacity (20%)	x 2 usual capacity (100%)	x 3 usual capacity (200%)
Resources	local	regional/state	national

New York City, Spring 2020

Adapted From, Surge Capacity Principles, CHEST

Case Study: Planning For Chaos
New York City, COVID-19

Staff Recruitment:

"With so many staff members out and so many new patients, the array of doctors, nurses, pharmacists, and respiratory therapists who were accustomed to working in the ICU needed reinforcement - All people who are good with knives and big needles..." – Sheri Fink, Code Blue

Not only were beds in desperately short supply, but there were not enough staff members to provide care for the patients flooding into New York City hospitals in unprecedented numbers. Staff was recruited from other states to help meet the need, doctors and nurses were called out of retirement, and hospital caregivers got creative. The following strategies were implemented:

- Tiered staffing structures were implemented, with ICU doctors and nurses leading teams of non-ICU providers. This approach significantly expanded capacity to deliver high-quality critical care.
- Manual proning (turning a patient over or turning a patient on their side) was performed under the direction of surgical teams with experience performing the maneuver in the operating room.
- Anesthesia physicians and nurses, who were not working due to a shut-down of the City's operating rooms, performed endotracheal intubations and obtained vascular access. This liberated ICU physicians from those tasks and thus expanded their capacity for patient care.

Mufid Majnun Unsplas

Pandemic Measure #1:
Adapt The Way We Work

"Organisms at the edge of chaos tend to be highly adaptive."

- Gustav Koehler, Guenther Kress, Randi Miller. What Disaster Management Can learn from Chaos Theory

- **Set Aside Traditional Top-Down and Linear Approaches:** to disaster management which are no match for the daunting challenges present in large-scale disaster situations.
- **Do Not Rely on a Hierarchical Management Structure:** which will restrict information flow and inhibit innovation.
- **Create Semi-Autonomous "Messy" Groups:** to solve problems in the field. This is a successful flat, decentralized disaster management structure.
- **Facilitate Effective Response Through Design:** support infrastructure processes that enable the response to rapidly organize itself. **Example:** providing a horizontal, deeply redundant communications system with sufficient capacity.

Pandemic Measure #2:
Increase Capacity

"Strategy to increase capacity should make use of resources you have first – provide surge in-hospital before considering an ACF."

- U.S. Department of Health & Human Services. Medical Surge Capacity and Capability

- **Follow Recommendations for ICU Capacity Increase During Pandemic Surge:**
  - **Immediate Conventional Response: 20%**
  - **Contingency Response: 100%** (using local and regional sources)
  - **Crisis Response: 200%** (using local, regional, national and international sources)

(U.S. DOH, WHO, Johns Hopkins Center for Health Security)

- **Provide a Core Number of Acuity Adaptable Units:** (where allowed by code) to allow for additional ICU capacity as needed.
- **Remember Staff Increases:** come along with patient increases and configure work areas to be expandable.
- **Create a Resilient Supply Chain:** by appropriately sizing supply areas and possibly introducing a Consolidated Service Center.
- **Design-in Flexibility:** for waste, sterilization, and decedent body handling surge requirements.

Pandemic Measure #3:
Provide Infection Control

"If a hospital has not put in place adequate measures to prevent and control infection, it may amplify an epidemic by spreading the infection to patients, staff, and visitors."

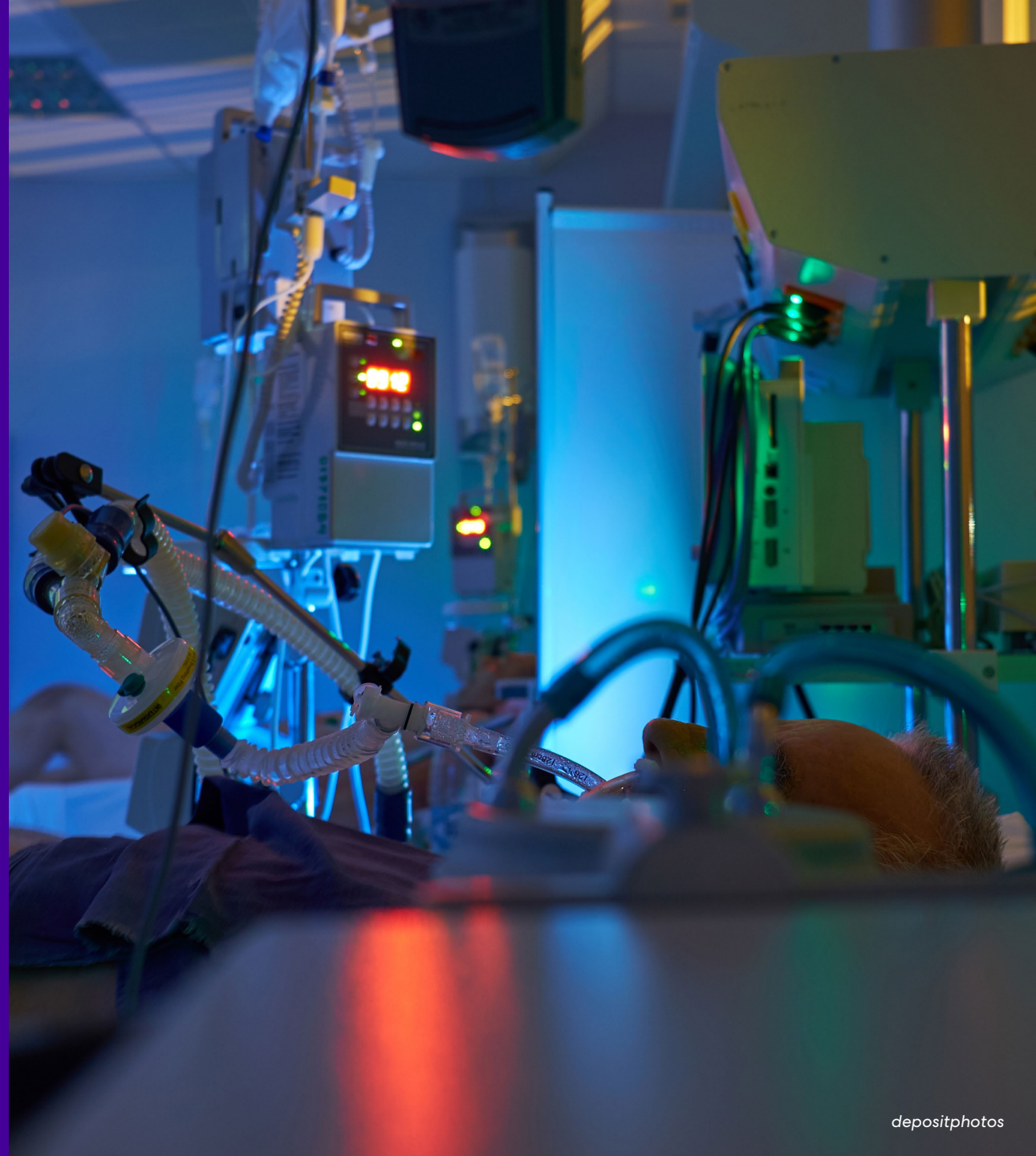
- WHO. Hospital Preparedness for Epidemics

- **Leverage Technology Systems:** like Telehealth to keep patients and visitors out of the hospital when possible.
- **Re-Think Circulation and Waiting Configurations:** to distance and separate infectious and non-infectious patients in pandemic and non-pandemic conditions.
- **Cohort & Include Flex-Isolation Units:** that can operate normally and be easily converted during a pandemic.
- **Support Front-Line Worker Health/Safety:** by configuring spaces to limit exposure, allow availability of adequate personal protection equipment, and provide respite.
- **Ensure Continued Safe Use of Vital Hospital Services:** like the OR's, by designing-in the ability to accommodate infectious patients without compromising the care of non-infectious patients.
- **Incorporate Higher Standards of Ventilation and Filtration:** recommended by clinicians and Engineers based on their experiences with COVID-19.

Why The ICU?

'At the peak, our facilities had transformed into large ICU's.'

- New York City physician practicing during the COVID-19 surge



Why The ICU?

Testimonial:

The recent pandemic surge in New York City was the most devastating medical scenario I have experienced in 40 years. We were dealing with a virtual tsunami level of illness with incredible mortality associated with it. During the peak, there were 2700 COVID patients in the hospital, 800 of those were ventilated in the ICU. If you don't have enough ICU beds, you can't get through it. We've crossed the Rubicon on this. We can't go back to where we were.

– President and CEO of a major New York City hospital

"Watching patients in the beginning was absolutely terrifying..."

- ICU Nurse who treated one of the first COVID cases in the US

The ICU is Crucial in A Pandemic

After the ED, the ICU is the main line of defense in a pandemic response. Intensive Care Units provide care to patients with severe or life-threatening illnesses and injuries which require constant care, close supervision from life support equipment, and medication in order to ensure normal bodily functions. Studies show that 22% of all deaths in the US occur in the ICU.

"The Intensive Care Unit (ICU) is a specialized hospital unit dedicated to the care of patients requiring life-support and those at extremely high risk for organ failure and death. Death and dying is a daily occurrence in the ICU forcing the teams to function in a highly charged emotional environment characterized by persistent grieving and moral distress.

With regards to the physical environment of the ICU, near constant alarms, uneven lighting, poorly placed equipment, and space limitations can mean that the physical environment is at best not helpful and at worst harmful to the goals of team-based critical care." -Teamwork in The Intensive Care Unit, Jennifer Ervin, Jeremy Kahn, Taya Cohen, Laurie Weingart

Why The ICU?

The ICU vs. The Alternate Care Site

From March through June of 2020, the need for ICU beds in New York City was so great that several non-hospital Alternate Care Sites were set up to care for ICU patients. One of the challenges with these sites is that the facility construction and configuration is sub-clinical and does not meet code or the current best-practices of critical care. Among these were: the Javitz Convention Center, The United States Naval Service Comfort Hospital Ship, and the Central Park Tent Hospital.

Another issue with these sites is operational. Someone needs to run them and to care for the patients. Hospitals and Health Systems must take them on and they simply do not have enough staff, especially during a pandemic, to send groups to sites far away from the parent hospital. Whether designed from scratch or retrofitted, the ideal scenario for most hospitals is to be able to handle the surge within the hospital itself.

"Talking to clients, most want to be able to handle their surge within the hospital. It becomes very difficult to staff an ACS when you only have so much staff."

– *Marvina Williams*

Case Study:
ICU vs. Alternate Care Site

"I don't know how they were able to set up decent air exchanges in the tents (during the COVID serge) and they don't have everything at their fingertips, obviously. There were probably a lot of runs back to hospitals. And nobody likes crickets in with their patients."
- Lynne Ingle

Converted Chicago Hospital:

The 4 week-long conversion of a shuttered Chicago Hospital to a Tier 2/2A/3, 585 bed, ICU Level, COVID Facility was a truly a heroic feat by the design, construction, and management teams involved. The conversion provides desperately needed surge capacity for the Chicago area going forward.

As an older facility built for a different function, the ACS faces some challenges not found in as ICU located in a more modern, operational hospital building.

- Patient visibility/patient separation is provided through doors with windows or through cubicle curtains (vs. ICU glass breakaway doors).
- The thru-widow HVAC units brought in to create negative pressure block most of the light, so the rooms are dark.
- Food Service, Lab, and Pharmacy are all provided off-site.
- The loading dock is functional but there are some misc. storage issues - like the lack of properly rated rooms to house oxygen tanks.

ICU Unit

‘A dark room with no alarms or phones.’

- Item #1 on Wish List of ICU nurse treating COVID-19 patients

ICU Unit

Testimonial:

"Saw my first COVID patient give up last night. He was struggling to breathe, maxed out on oxygen. It was time to drop a line and intubate and he said, 'No, just let me go.' Honestly, my heart hurts and any confidence I had last week is gone and I'm back to being scared shitless."

– Tweet from Nurse treating COVID-19 patients

"I'll never forget an overnight shift in the ICU in April. Got called in for a cardiac consult. 2 AM. Lights were off. 40 COVID patients in beds around an oval unit. Everyone sedated and intubated. Quiet as a graveyard. Scariest thing I've seen in 20 years of medicine."

- Cardiologist treating COVID-19 patients

"When I was admitted, I was told that, if they put me on a ventilator, I had a 50/50 chance of survival. As not going on a ventilator was a zero chance of survival, I said yes."

- COVID-19 patient

Unit Planning Considerations

ICU beds, and by extension the ICU unit, were the most in-demand resource during the spring 2020 COVID-19 surge. The ICU Unit is the most fundamental module in long–term critical care treatment (vs. short-term care received in the ED). It is a complex set of spaces that serve to support life-saving care, the people who are saving lives, and those being saved. The extreme nature of day to day ICU practice has sorely tested ICU design over the years. The COVID-19 surge served to test it even further.

It is important that recommendations for the adaptation of the 12-Bed ICU Unit made to accommodate a future Infectious Pandemic Surge be responsive to the need. In addition, suggestions should enhance the best-practice unit design rather than replace elements that successfully support patient care and have taken years to develop. The following recommendations incorporate studies of the evolution of ICU Unit design as well as crucial feedback from front-line clinicians during the first wave of COVID-19.

Case Study: ICU Unit

Space Allocation in Award Winning ICU's of The Last Two Decades

Study Scope:

The study includes a set of 25 adult ICUs that were awarded between 1993 and 2012 by the Society of Critical Care Medicine (SCCM), the American Association of Critical Care Nurses (AACCN), and the American Institute of Architects/Academy of Architecture for Health (AIA/AAH) for their efforts to promote the healing of critically ill and injured patients through the design of the critical care unit environment.

Type :

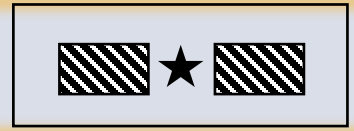
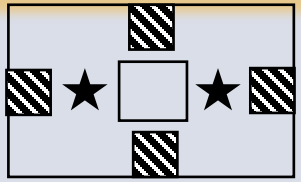
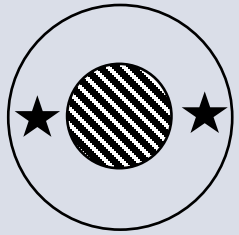
The racetrack layout has been the most dominant unit type among award winning ICU's during the last two decades...it provides more space and perimeter wall for more patient rooms with natural light and outside views, it accommodates more compact and centralized support and helps reduce the physical distance from patient rooms to support areas. Some studies show that radial units perform better than single and/or double corridor units due to better visibility and shorter walking (Shepley & Davies 2003).

Size:

"The size of an ICU must be appropriate for constant visibility of ICU patients by providers. It must also be appropriate for care providers to be fully aware of all the people, not just the patients and activities on the floor. Additionally, the size must also be appropriate for less walking and noise." – Rashid Mahbub, Space Allocation in Award Winning ICU's of The Last Two Decades.

The SCCM Guidelines recommend maximum 8-12 beds per unit for better observation. In general, larger ICU's with more beds have more acquired infections. The study shows the average number of beds for all the units was 24, which is a much higher number than the numbers recommended by SCCM.

ICU Single Unit Configurations:
Including Racetrack Layout

Type	Diagram
Ward	
Single Loaded Corridor	
Racetrack	
Courtyard	
Radial	

ICU Unit

Proposed Unit Planning Considerations

The number of beds required in an ICU is client dependent so solutions starting with a 12-bed unit that could be expanded to 24 and 48 beds offers flexibility and maintains appropriate staffing ratios of nurses to beds. The proposed 12-Bed ICU Unit maintains an overall set of configurations that allow for efficient, flexible, and effective operations that translate into optimal patient care.

Proposed ICU Unit Diagram

The Proposed Infectious Pandemic Surge 12-Bed ICU Unit diagram, which will be discussed in detail in this section, represents the determined functional and space planning requirements based on the research and interview data acquired during this study. Figure 6 shows regular functions, as well as pandemic surge functions. Some considerations are listed below:

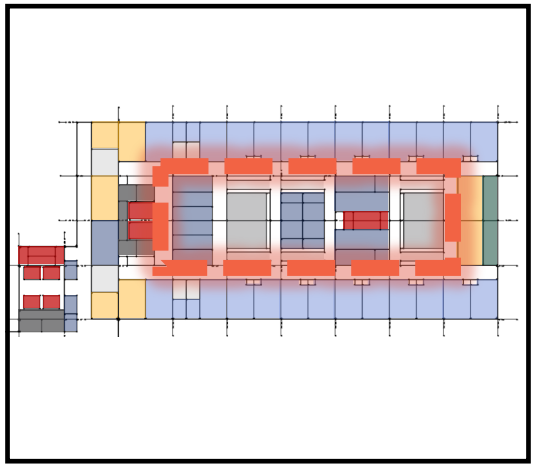
- Patient Surge: It is planned to allow for a surge capacity of 100 percent - or a doubling of patient beds, which are accommodated at two per patient room.
- Support Surge: Staff support, and clinical support areas are configured to flex up during surge, allowing for more supplies and more caregivers to be on the unit.
- Isolation Unit: The unit planning supports the conversion of the unit to a self-contained isolation unit during infectious pandemics.
- Safety: Other important infection control and staff amenity features that serve to protect staff as well as patients are given a high priority.

"What I would want as a client is something that is flexible enough for me to be able to expand if I wanted to expand it and had the budget to do it. "

- Anthony Mistretta

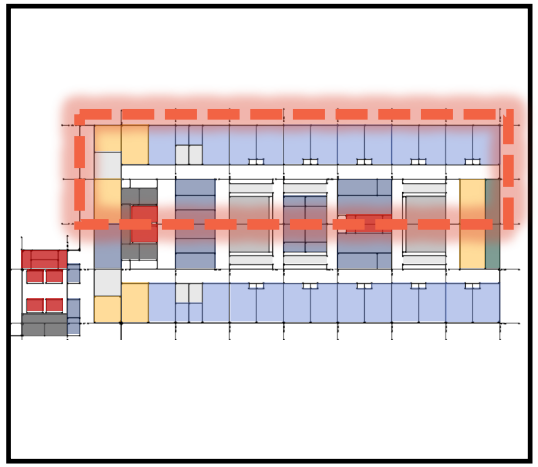
ICU Unit

Proposed Configuration:



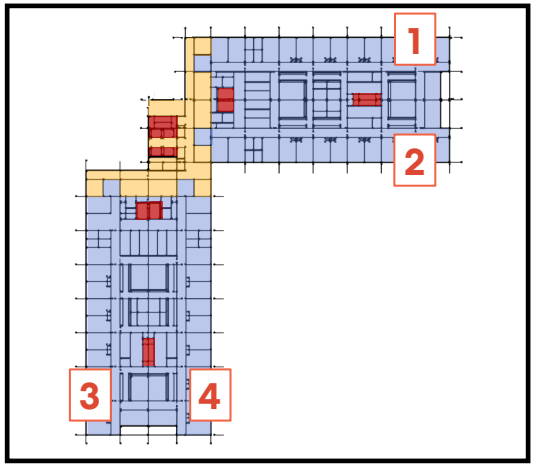
Racetrack

ICU Study – most effective



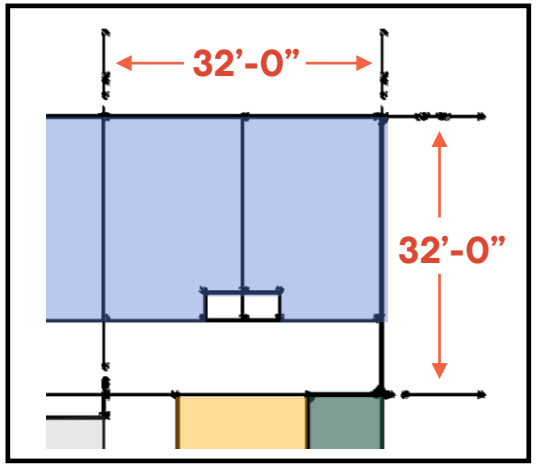
(2) 12-Bed Units = 24

ICU Study – optimal size
Up-scales to 48 beds



Overall Floor Plate - L-Shape (4) Units

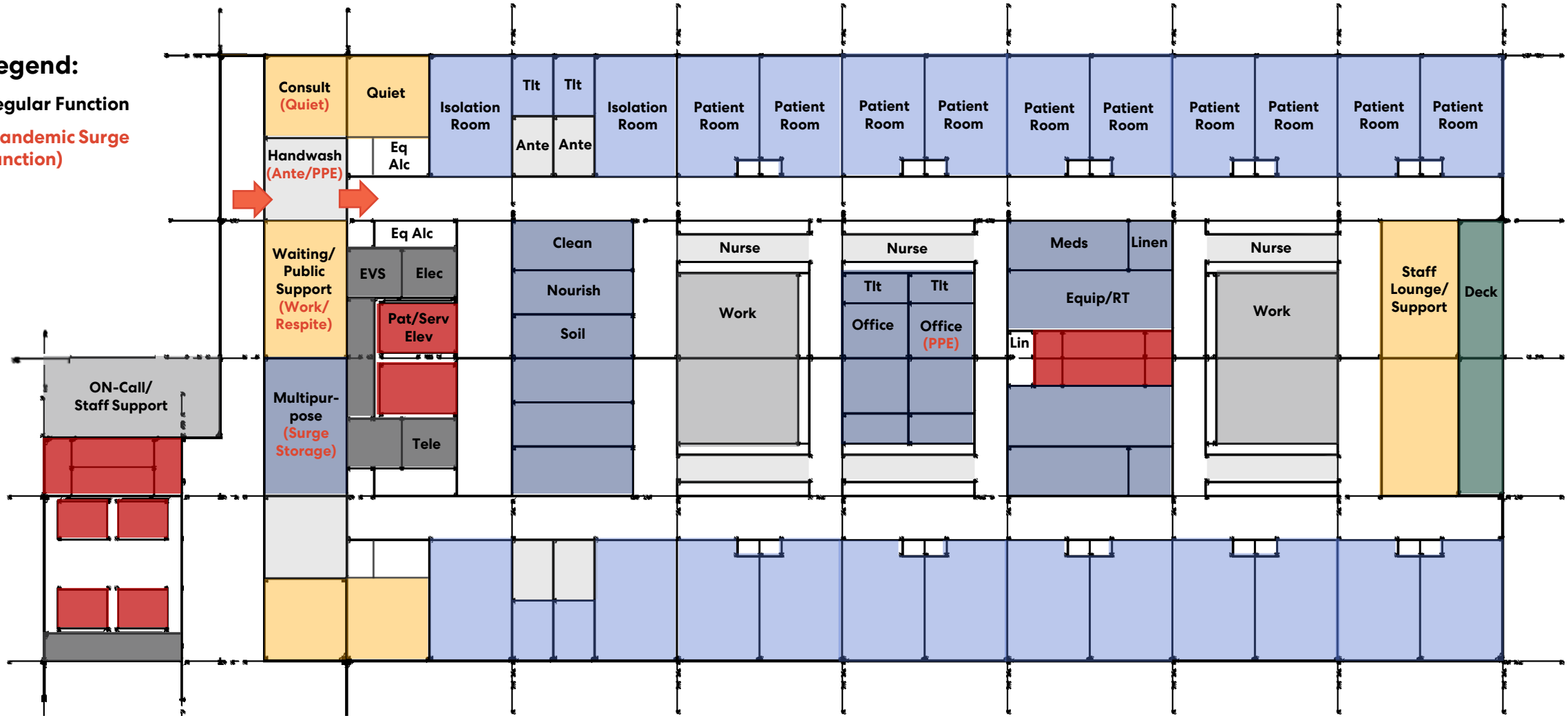
Efficient - fits in smaller site footprints
Discreet wings support cohorting



Rooms on a 32'-0" Grid

Accommodates FGI and OSHPD clearances

ICU Unit Diagram



Case Study: ICU Units Adapt
New York City, COVID-19

Creative Staffing Solves Personnel Shortages:

"Manual proning, an intervention that puts a patient in a prone position to improve gas exchange, used in patient with COVID-19 induced respiratory failure, was performed under the direction of surgical teams with experience performing the maneuver in the operating room. Critical Care nurse and physicians formed these proning teams. Anesthesia physicians and providers staffed procedural teams to perform endotracheal intubations and obtain vascular access. This liberated ICU physicians from those tasks and thus expanded their capacity for patient care. Tiered staffing structures used ICU doctors and nurses to lead teams of non-ICU providers to manage the volume of patients. This approach significantly expanded capacity to deliver high-quality critical care." - Critical Care and ED Response at The Epicenter of the *COVID-19 Pandemic*

"Critical Care staffing was supplemented by temporary recruits, volunteers and Department of Defense medical personnel." - Critical Care and ED Response at The Epicenter of the COVID-19 Pandemic

Increased Demand On Support Spaces:

"One of the biggest lessons learned (curing the COVID-19 pandemic) is that the EVS closets and the Soiled Utility Rooms need to be bigger than the current code requires them to be. They were completely inadequate in the hospitals of almost every single client I have spoken to. When you are donning and doffing for 24 beds every single time every single person goes in there, the waste that is coming out is astronomical. I don't think people realize how fast the waste piles up. Increasing pick-ups in these rooms would also work but only if there is the staff to do it – which there wasn't." - Anthony Mistretta

Vladimir Fedotov, Unsplash

ICU Unit – Contributor Wish List

(#1 Adapt the Way We Work)
Provide Respite Room

"Outdoor space. A nice garden where we can go out and eat lunch."

- Hospital Department Director

"A nap room with La-Z-Boys."

- Nurse treating COVID-19 Patients

(#2 Increase Capacity)
Add More Isolation Units

"We pushed out the patient room windows and brought in (HVAC) machines. They were SO LOUD."

- Nurse treating COVID-19 patients

(#3 Provide Infection Control)
Give Us PPE Cabinets

"I didn't become infected with COVID because I wore PPE."

- Physician treating COVID-19 patients

"We have wall-mounted PPE cabinets in the hallways with card access. People steal PPE, mainly the visitors."

- Nurse treating COVID-19 patients

"I don't like the idea of using one set of PPE for all patient rooms, even if the unit is an isolation unit. I feel like we would be protecting ourselves and not the patients."

- Nurse treating COVID-19 patients

ICU Unit

Addressing the ICU Unit Contributor Wish List

Diagram – Staff Support

The diagram shows design strategies for the proposed ICU design that support medical staff. During a pandemic it is essential to maintain the health and safety of the people who are saving lives. The front-line hospital workers who reported to work daily during the 2020 March through June COVID-19 surge in New York City faced overwhelming horrors while treating patients, friends, and colleagues. The stress of treating people with an out-of-control mystery virus took an enormous toll on the health of these workers.

Institutions like Mount Sinai Beth Israel in Manhattan implemented make-shift respite rooms for staff on hospital grounds. Self-reported stress dropped 60 percent after just 15 minutes in the rooms.17 The Proposed ICU design incorporates the following features in support of the staff:

Staff Respite

- Permanent Staff Lounge: A permanent Staff Lounge is provided out of the way at the end of the unit with direct access to an outdoor terrace. (see 4.4.3 Hospital Contributor Wish List - outdoor space is another highly requested item for reducing stress).
- Flex Staff Lounge (off Unit): A second pandemic flex Staff Lounge is provided off the unit in the waiting room space which will not be used during a surge (visitors are not allowed inside the hospital). Providing respite off the unit is key to limiting distractions. Keeping it nearby allows staff to return to the unit quickly if needed. (Note: this space could also be used for additional workspace).
- Quiet Rooms: Two quiet rooms are provided as well. One is on the unit (can also flex as a lactation room) and the other is a flex consult room located near the public waiting room.
- On-Call Rooms: Are provided on the floor for Staff who need to sleep between shifts.

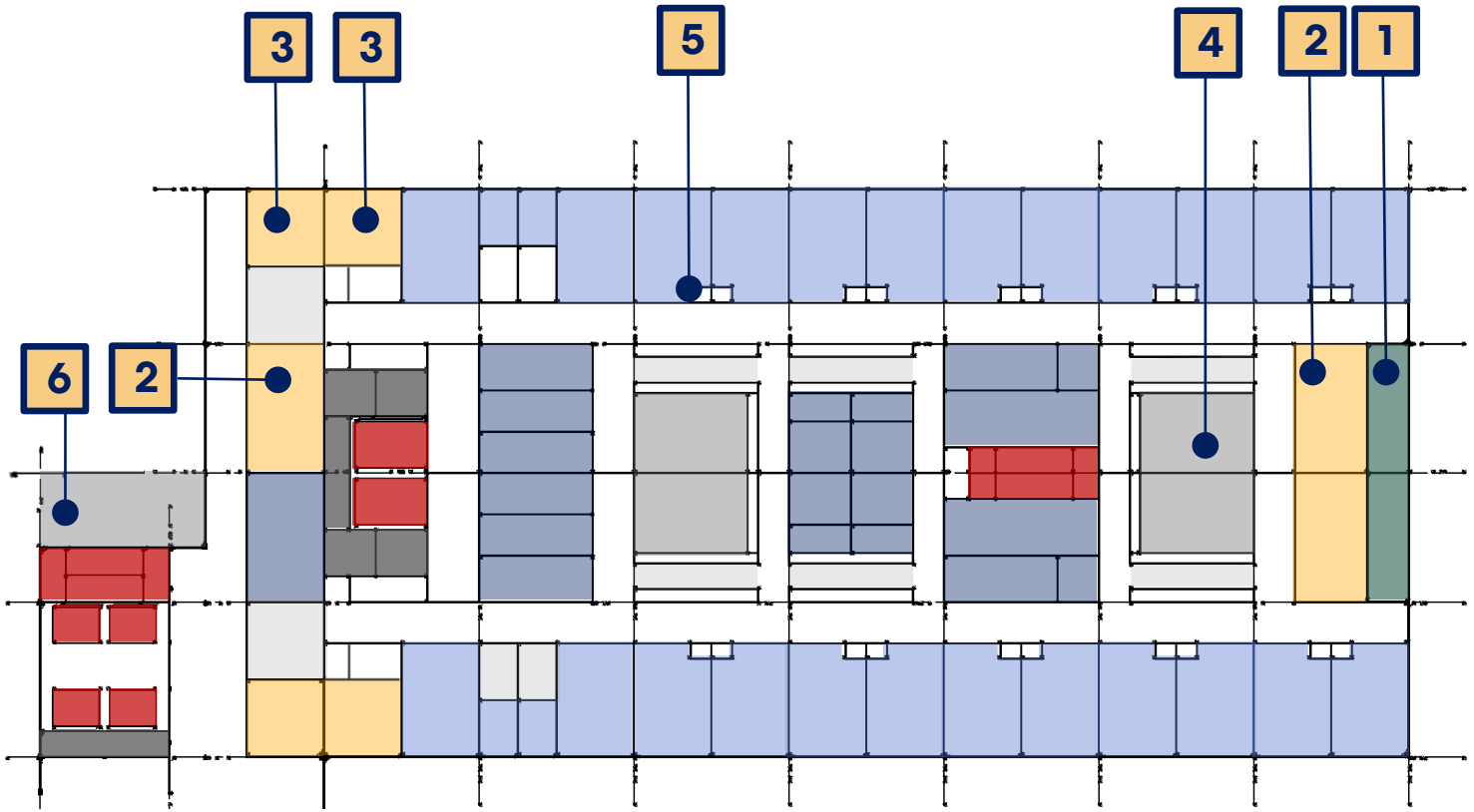
"If you ask a clinician what their wish list is, they will say shorter hours and less stress. These aren't things we can address with design solutions, but we can enhance the human experience by providing respite outside units with views to light and air."

- Chuck Siconolfi

(#1 Adapt the Way We Work)
Provide Respite Room

ICU Unit – Staff Support

1. Terrace for Staff Respite
2. Staff Lounge/Support On and Off Unit (Flex)
3. Quiet Room – On and Off Unit (Flex)
4. Flexible Work Zones
5. Caregiver Substations Outside Rooms for Charting Monitors, PPE
6. On-Call Rooms



ICU Unit

Staff Work

- Work Areas: Are sized for social distancing or additional staff.
- Flexible Work Zones: Nurse Stations back up to flexible work zones that allow for a variety of configurations.
- Caregiver Substations: Provide enhanced facilities for charting and patient care (see 4.3.4 The ICU Room for more information).

Diagram – Isolation Unit

Current ICU design best practices and regulatory standards provide for one or two negative pressure isolation rooms per unit to house the small number of infectious patients that enter the hospital for treatment on a daily basis. During an infectious pandemic, this number becomes woefully inadequate. For this reason, hospitals are increasingly interested in designing whole units with the ability to flex into negative pressure isolation units in emergency situations. This can be a challenging and expensive proposition. Even more challenging is the recent hospital demand for retrofits that will allow existing units to flex.

- The proposed solution is designed to allow the conversion of a 12-Bed ICU Unit into an isolation unit during an infectious pandemic.
- Mechanical (HVAC) System: The unit HVAC system must be separate from that of the main hospital and contain the proper filtration (see Case Study below).
- Ante Room: An ante room is provided at the entry and a smoke barrier is installed around the unit to ensure that the proper air pressure is maintained, and that no infection can spread beyond the unit itself.
- Dedicated Elevator: A dedicated service/patient elevator is provided to minimize mixing infected patients with the general population and minimize outside incursions into the unit.
- Infection Control: Additional infection control facilities are provided: gowning rooms (flexed Offices) and handwashing stations.

"When the isolation rooms are scattered throughout the unit, we aren't doing anything from an overall infection control perspective."

– *Anthony* Mistretta

Case Study:
Isolation Unit

"What's being discussed in the post-COVID design world right now: How do you flex a unit to become completely negative? How do you do it when you have an existing building and an existing mechanical system?" – Anthony Mistretta

The Case for Isolation Units:

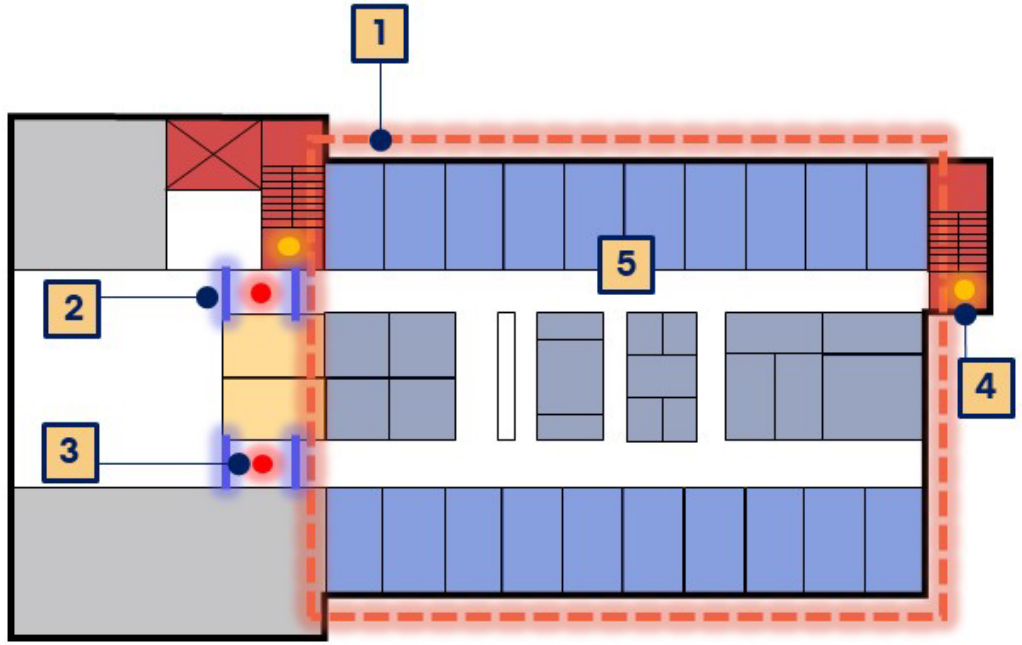
- **Respiratory Transmission:** The 2017 Johns Hopkins Bloomberg School of Public Health Center for Health Security paper, *The Characteristics of Pandemic Pathogens,* states that the respiratory route is the mechanism of transmission most likely to lead to pandemic spread. This is because interventions to interrupt this method of spread are more difficult to implement. Isolation Units are one such method.
- **Cohorting:** Placing patients infected with the same pathogen in the same unit is recommended by the CDC, WHO, Johns Hopkins Bloomberg School of Public health.
- **PPE:** some (not all) clinicians and health organizations feel Isolation Units can reduce the need for donning and doffing each time a caregiver enters a patient room. (Note: some feel that patient safety mandates continuing this practice even in Isolation.)

Successful Isolation Unit Retrofit Test Model: (2015 findings published in the American Journal of Infection Control, 2017)

- **Functioning Hospital:** A functioning hospital in the San Francisco Bay Area was used.
- **Chosen Ward:** the chosen ward was located on a top floor where it could be effectively isolated. It had an existing dedicated air handling unit, a dedicated bathroom exhaust system, and a firewall separating it from the rest of the hospital.
- **Modifications:** the AHU was set to 100% outside air and 100% exhaust. HEPA-filtered negative-air machines were operated in the ante room created at the entry. The fire doors were closed to seal the unit off.

Successful Temporary Isolation Unit

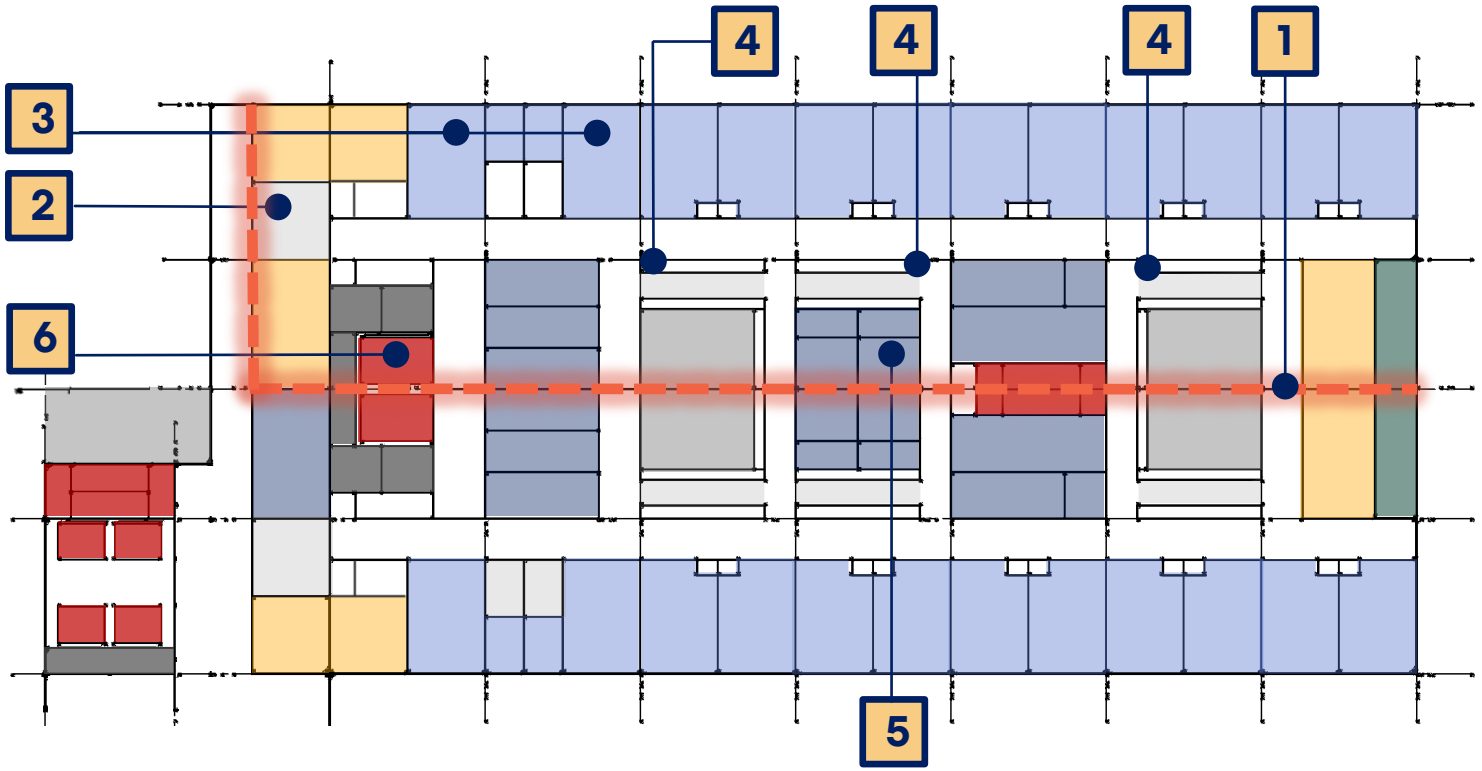
1. **Existing Rated Construction with Closed Fire Doors**
2. **Temporary Ante Room Created at Entry – Wood Frame Walls with Plastic Sheeting**
3. **2 Portable HVAC Units with HEPA Filters Added to Establish Negative Pressure**
4. **Temporary UV Lighting Added at Slightly More Positive Stairwells (to Neutralize Escaping Infectious Elements)**
5. **Existing Unit HVAC Temporarily Set to 100% Outside Air and 100% Exterior Exhaust**



(#2 Increase Capacity)
Add More Isolation Units

ICU Unit – Isolation Unit

1. Smoke Barrier Provides Unit Isolation
2. Ante Room at Entry – Handwashing & PPE
3. Optional Added Isolation Rooms
4. Additional Handwashing Sinks at Nurses Stations
5. Additional Gowning Room (Flex)
6. Dedicated Unit Elevator



ICU Unit

Diagram – Clinical Support

PPE

Best practice dictates that staff must put on fresh PPE each time they enter an infectious person's room. Upon leaving, the used PPE must be taken off and disposed of properly (or cleaned and re-used). The PPE should not be worn into more than one room. While reusing PPE when treating more than one patient may continue to protect the caregiver, it will expose the patient to previous patients' infections. In the case of COVID-19, it has been shown that increased viral load carries increased morbidity.

Placing multiple PPE cabinets and disposal bins between rooms (instead of forcing care givers to don and doff in a gowning room that may be far from the patient bedside) considerably improves the workflow for staff working in those rooms. The amount of PPE gear required can be considerable depending upon the infection.

Design Strategies for Clinical Support

- **Distributed PPE Cabinets**
- **Enlarged Clinical Support Spaces**: One of the biggest lessons learned during the COVID-19 pandemic is that some of the clinical support spaces are not currently sized to handle pandemic volumes. Supply rooms are the obvious culprits, but the environmental services closets and the soiled utility rooms also need to be bigger than the current code requires in order to handle the volume of waste generated in a crisis event.

  In the Proposed 12-Bed ICU Unit Plan, clinical support spaces are up-sized approximately 8-10 Additional flex pandemic storage is provided off-unit in a conference room.
- **Disneyland Concept:** Major supply storage and waste rooms are back-fed through a dedicated elevator lobby by a dedicated elevator allowing material to be transported without coming into contact with patients.
- **Imaging Alcoves**: Larger imaging alcoves are provided to make sure portable imaging can be provided on the unit, keeping fragile, infectious patients in their rooms.

"Because getting PPE's was such a problem and they were making people wear the same thing over and over again, having the ante room at the beginning of the unit was possibly the only viable idea."

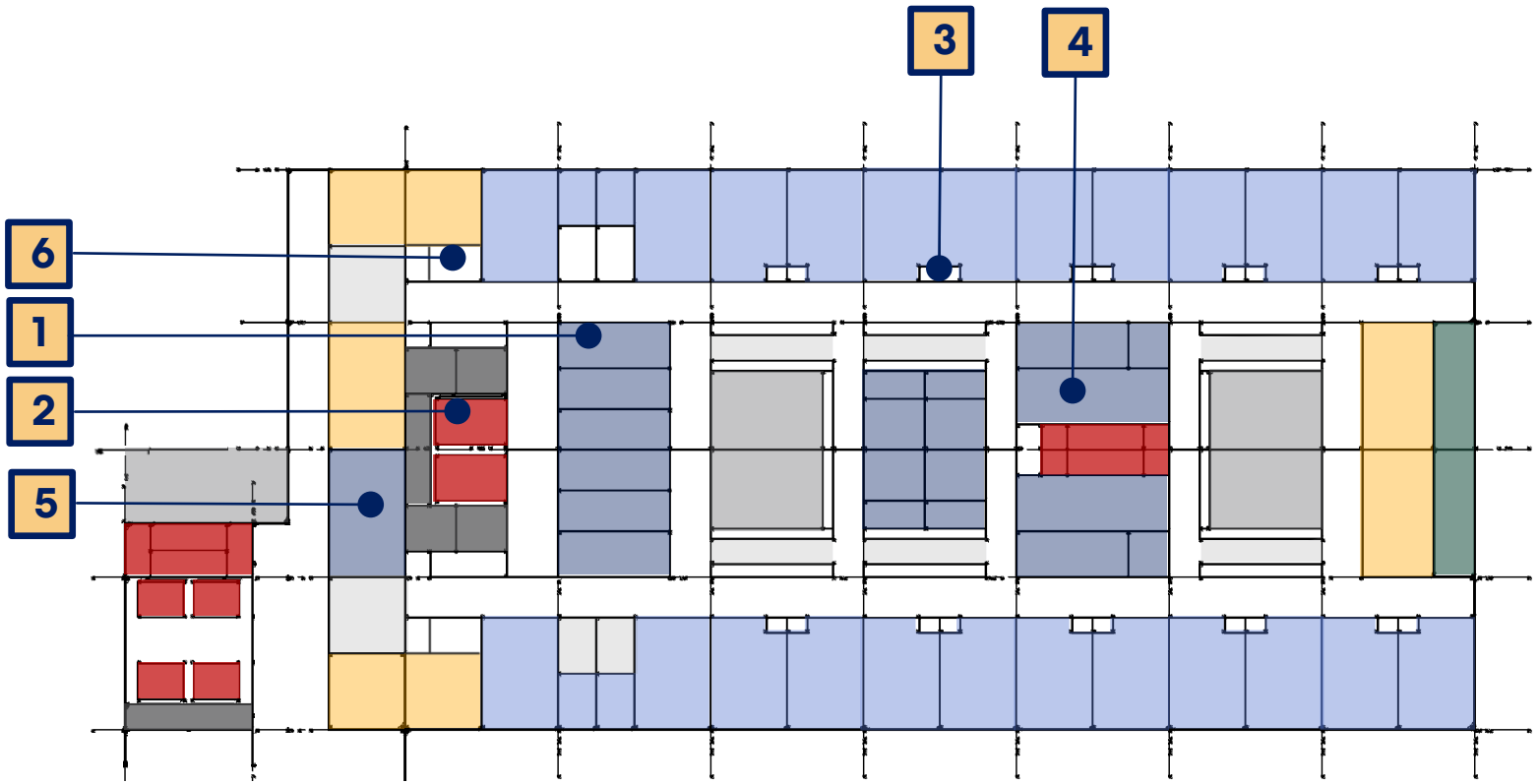
- Lynne Ingle

(#3 Provide Infection Control)
Give Us PPE Cabinets

Required PPE:	Mask	Gloves	Face Shield	Gown	Apron	H2O-Proof Boots
Airborne	X	X	X	X		
Ebola	fluid-resistant	double	X	impervious	H2O-proof	X

ICU Unit – Clinical Support

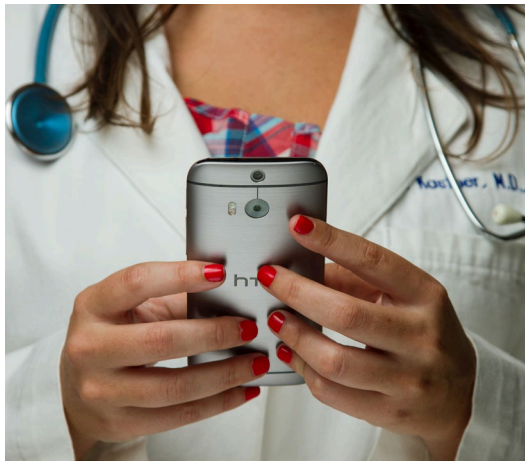
1. Disneyland Concept: Back-fed Support Rooms
2. Dedicated Unit Elevator
3. Distributed PPE Cabinets
4. Larger Support Rooms
5. Pandemic Surge Back-Up Storage Off The Unit (Flex)
6. Large Imaging Alcove



ICU Unit - Technology Solutions

"Technology needs to respond to a particular need. It needs to support people. It can't be technology first."

- Phil Crompton



National Cancer Institute, Unsplash

Alarm Fatigue

"The biggest problem in the ICU is that everything is alarmed. After about a week, the staff put their phones in their pockets because they can't handle it anymore. There are so many alarms in a hospital, no human brain can process them all. The next generation of alarm systems filter to reduce alarm overload."

Javier Matheu, Unsplash

Monitoring

"An ICU has an awful lot of monitoring now. I don't think there is a box of pandemic equipment that you would deploy. A lot of the new technology helps just as well if we're not in a pandemic situation."

Owen Beard, Unsplash

Telehealth

"Lots more video telehealth within the room. Next generation of telehealth: testing, imaging, monitoring. What's next? At-home do it yourself ultrasound."

Luke Jones, Unsplash

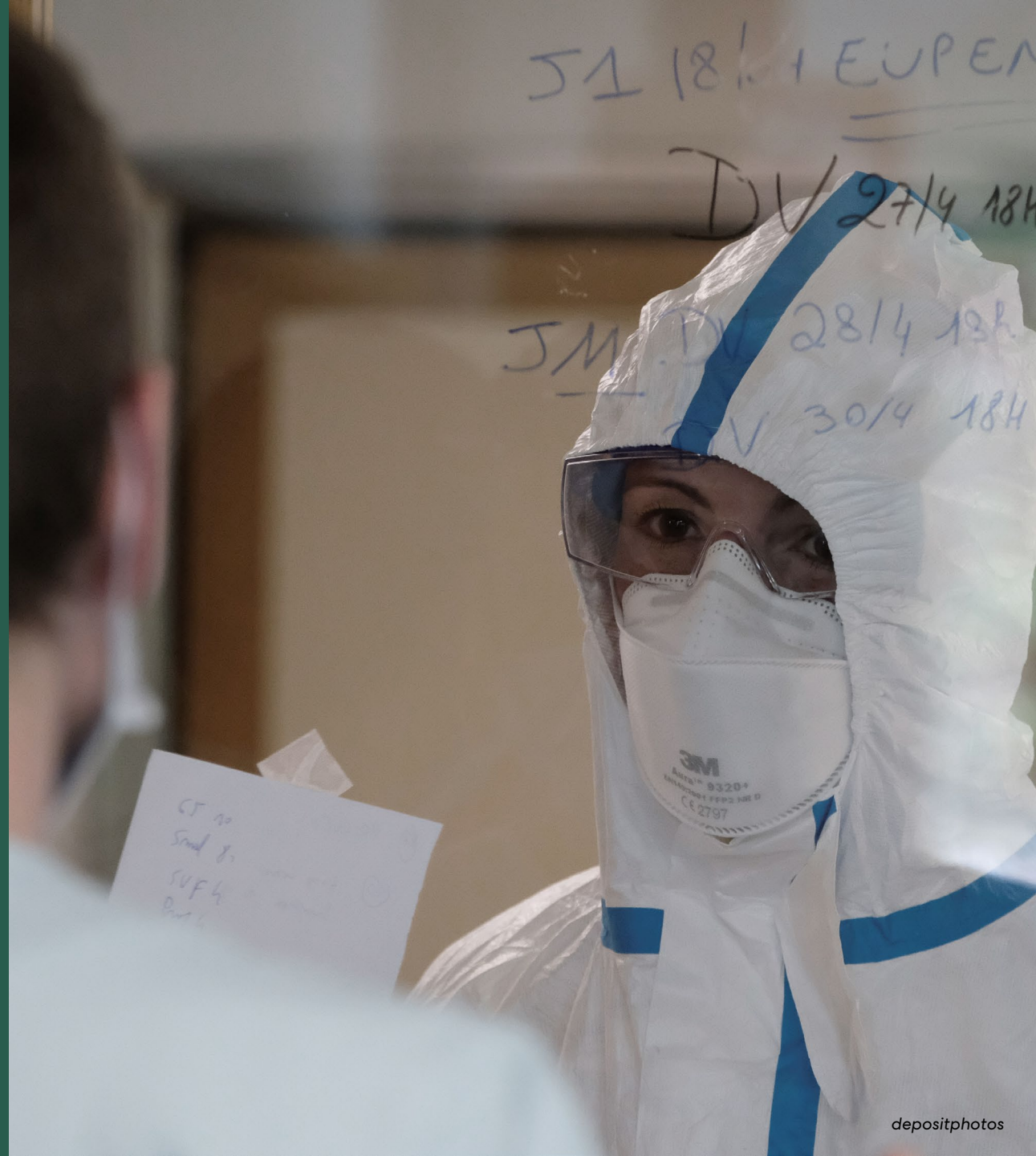
Tracking (RTLS)

"There's a badging system called 'Friend or Foe.' If you want to make sure your staff doesn't go within 6 feet of an infectious patient without knowing it, you can badge them up. If they go closer, the badge will beep at them. This is actually being used by the NFL to ensure the players maintain social distancing during training camp.

Room

‘Every time the pulse-ox went off we had to gown up to go into the room. It was a time-consuming hassle.’

- ICU Nurse treating COVID-19 patients during the surge



depositphotos

ICU Room

Testimonial:

"It's the COVID-19 Pandemic, early days, when my cousin sends me the txt. There's a video - something about UK physicians and a thing called 'proning.' My cousin is a graphic artist who worked some years at the San Francisco Zoo so her txt's are usually good for something absurd and animal related. I have nothing to do except lie in bed and try to move the cement block now occupying the lower third of my lungs up and down so I can take a breath. I click, ready to laugh. But it's not funny.

Instead, it's rather miraculous. In the midst of this global whirlwind of people being rushed to the ER gasping for breath - only to be intubated, put on respirators, and die, these doctors have simply rolled people over on their sides and may have saved their lives. Now, my cousin is no stranger to respiratory distress herself, having almost died as her Lupus-compromised immune system caused her body to attack her lungs 10 years ago. So, I take this suggestion seriously. I try it immediately and I roll over onto my side. I can breathe."

- ***Author, COVID-19 patient***

"Proning – it didn't make me laugh but it might have saved my life."

- Author, COVID-19 patient

Room to Work

Providing enough space for caregivers to work in the ICU room is key during normal operations. During a Pandemic it is crucial. Patients will be sicker and in crisis. They will need more care from more people - fast. How much space is enough changes as care changes.

One recent, useful study made by the Department of Human Sciences at Loughborough University (UK) describes a series of functional experiments undertaken to test the spatial requirements for various nursing functions performed in the room. The analysis found that an average of 250 SF (23.26 SM) was needed to perform a bed to bed transfer and 246 SF (22.87 SM) was needed for resuscitation.

ICU Room

Proposed Infectious Pandemic Surge ICU Room

The proposed Infectious Pandemic 12-Bed ICU Unit is planned to allow for a surge capacity of 100 percent - or a doubling of patient beds, which are accommodated at two per patient room. Because the cost of hospital construction can be upwards of $1,000 per square foot (varies by state), increasing the size of the patient room to accommodate two patients in a surge situation can be prohibitive. For this reason, configuring the room to work for two patients as well as one becomes imperative.

When doubling-up patients in a room, it is important to remember that there may be half a dozen people in those rooms at any one time: nurses, doctors, respiratory therapists, someone doing dialysis, etc. Code required clearances may be relaxed during an emergency but functional clearances must be maintained. During the spring 2020 COVID-19 surge, family sleep couches, side tables, and guest chairs were moved out of the rooms to allow caregivers space to work.

Diagram – Proposed ICU Room Configuration

The proposed ICU Room configuration accommodates two patients as follows:

- **Maintaining Proper Clearances:** Facility Guidelines Institute (FGI) and the California Office of Statewide Health Planning and Development (OSHPD) clearances for one bed are maintained. Relaxed clearances, which are functional and historically allowable by regulatory agencies, are maintained for two beds.23
- **Toilet Room Configuration:** This is modified to ensure clearances for two beds. It is located outboard (on the outer wall) to provide maximum visibility by caregivers from the hallway.
- **Equipment**: Space for infectious pandemic equipment (ventilators, dialysis, etc.) is provided.

Diagram – 2 Patients in 1 Room: Providing Services

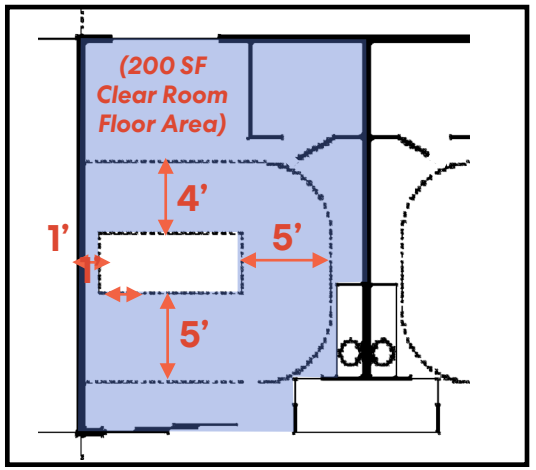
Doubling up on additional service infrastructure (booms, headwalls, etc.) can also be prohibitively expensive for health systems to consider. In most states, the number of code required services (medical gasses, vacuum and electrical) are almost enough to serve two patients. To mitigate cost, additional outlets can provided on the primary patient's delivery system (headwall, boom, in-wall unit) or an in-wall unit can be added directly over the secondary patient bed location to provide the additional services.

"I think it's a reality that you may have half a dozen people in those rooms at a time. Nurses, doctors, RT's, someone doing dialysis..."

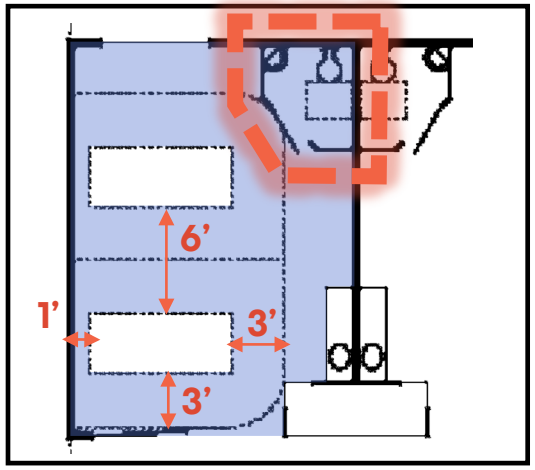
- Lynne Ingle

ICU Room

Proposed Configuration:

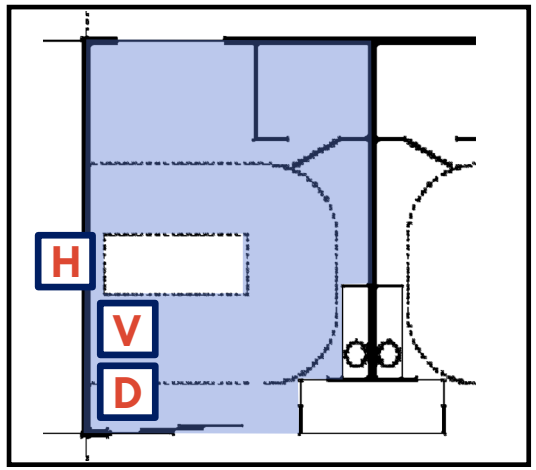


Bed Clearances
FGI
OSHPD

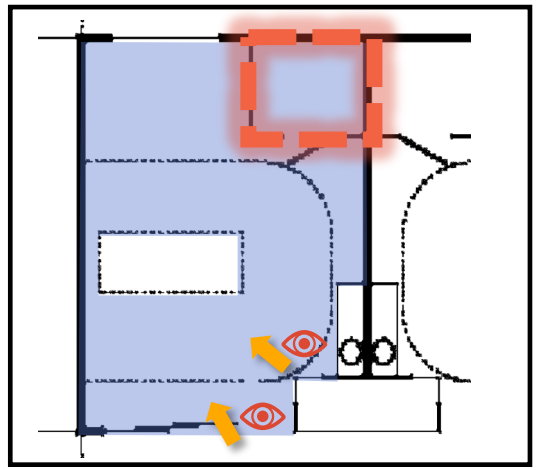


(2) Beds in 1 Room
6'-0" Between Beds – CDC

Toilet room must be configured to accommodate 1 and 2 bed clearances



Architecturally Significant Equipment
Headwall
Ventilator
Dialysis



Enclosed Outboard Toilet
Prevents in-room aerosolization of bedpan washer

Allows maximum visualization of patient from corridor

ICU Room - Proposed Services (2 Patients in 1 Room)

"There are a lot of hospitals that use booms in ICU. In trauma, they equip them so they can service two patients. The same could be done in ICU."

- Lynne Ingle

Gas	FGI	OSHPD
Oxygen	3	3
Vacuum	3	3
Medical Air	1	1

ICU - Required Gasses Per Bed

FGI
OSHPD

Sami Salim, Unsplash

Headwall

"Each patient needs O2, air, and suction. If you built the ICU headwall to meet usual (California) state requirements, you might be OK. Running lines to the second patient is the issue right now (the length)."

National Cancer Institute, Unsplash

Boom

"Often the booms are located on both sides of the patient. One side is the dry side. The other is the wet side. The wet side would have your ventilator on it."

Wikipedia

Covered Outlets

"A less expensive choice is to design the headwall for 1 patient and add thru-wall gas outlets only for the second patient, which are covered when not in use."

Case Study: ICU Room Challenges
New York City, COVID-19

Alcoves Between Rooms:

"Staff members had separated control boards from some of the ventilators, so they could adjust their settings and monitor patients without going inside their rooms unless necessary, reducing exposure to the virus. Nurses were making a similar adjustment with the pumps that delivered intravenous medications, adding extension tubing that snaked across floors to hallways. Workers rushed in and out of the rooms (to repeated warnings) "Watch out!, Don't trip!" – Sheri Fink, Code Blue

"I don't know how bad it was but, oh, man, they were using a lot of Infusion Pumps. Each pump has the ability to deliver 4 meds. Some hospitals developed tubing extensions so the pumps could be set outside the sliding doors and nurses could stay out of the rooms (because getting PPE's was a problem)." -

Equipment:

Dialysis: became vital to treating COVID-19. *"Often dialysis is an outside contract so they have portable dialysis machines that can come into the rooms. It's important to make sure the mobile dialysis unit has self-contained water because you have to have special water for dialysis. Sometimes there are places in the hospital where they can be refilled."* – Lynne Ingle

Ventilators: are key to treating life-threatening respiratory infections. *"They were sharing the types of ventilators we have now. The only issue there is that each patient has to be on the same ventilator settings Ideally you want to plan for at least 1 ventilator for each room, but no budget is going to be able to afford that. We're going to see a lot of different kinds of ventilators show up that aren't necessarily on the market at this very moment." – Lynne Ingle*

X-rays: "*Portable x-rays – bring x-rays to the bedside." – Lynne Ingle*

Adam Niescioruk, Unsplash

ICU Room – Contributor Wish List

(#1 Adapt the Way We Work) Add Windows

"Visualization of patients is key. We installed windows in our Med Surg unit doors when we used them for COVID patients."

"Through the window you can see a patient is having trouble breathing because they become lethargic and start using their chest muscles to breathe. You can see the O2 going down (on the pulse-oximeter). We can tell the patients to prone themselves using hand motions – we would flip our hands."

- Nurse treating COVID-19 Patients

(#2 Increase Capacity) Add More Isolation Rooms

"She had to intubate patients in double rooms. She couldn't move them – there wasn't time. Also, they were hooked up to IV's, monitors, gasses..."

- Chuck Siconolfi describing a Nurse Anesthetist intubating COVID-19 patients in the ICU during the 2020 spring surge

(#3 Provide Infection Control) Take Monitors Out Of Rooms

"Keeping monitors outside the rooms saves a lot of re-gowning time. Placing wireless vital signs monitors in alcoves right outside the room really helps."

- Nurse treating COVID-19 Patients

ICU Room

Addressing the Contributor ICU-Room Wish List

Alcoves Between Rooms – 2020 COVID-19

The PPE shortage due to supply chain failure, along with the unknown nature of COVID-19 transmission at the time, caused caregivers to employ extraordinary measures to stay out of the patient rooms. Staff moved what equipment they could outside the patient room doors, adding leads that snaked across floors. This created dangerous tripping hazards that could not only **cause staff injury but endanger patient care if the plug for a lifesaving piece of equipment was pulled out of the wall.**

Proposed ICU Room adaptations

- **Adding Windows:** Visualization is key in every ICU setting and is mandated by code. In an infectious pandemic setting where the patient's condition is more volatile and the progression of symptoms can even be unknown, it is even more crucial. Nurses interviewed report being able to tell when their patients stopped being able to breathe just by looking at them through windows. It is important to note that acute care patient rooms, which may flex as ICU during surge, also need windows in the doors.
- **Taking Monitors Out of the Rooms:** Keeping staff out of the patient rooms as much as possible is emerging as a best practice during an infectious pandemic situation. A charting station is often provided between two rooms in current ICU design. The proposed patient room enlarges this station to include patient monitors and accommodation for PPE. In the isolation room, the ante room has been revised in a similar manner.
- **Adding More Isolation Rooms**: Isolation rooms are expensive to build and difficult to use for regular patients when no isolation patients are present (ante room use must be maintained. Bypassing the ante room by using the regular sliding doors, which is a quicker and more convenient way to enter the room if the patient is not infectious, will cause alarms to sound as the pressure differential between the room and the hallway is disturbed). Codes in most states mandate a minimum of one per unit. A surge situation, where numbers have not reached crisis levels, benefits from more isolation rooms.24 The proposed ICU design provides an optional two isolation rooms per unit.

"It may become more critical to have an area outside the room to chart and monitor – not necessarily just have the physio-monitor in the room but also one outside it."

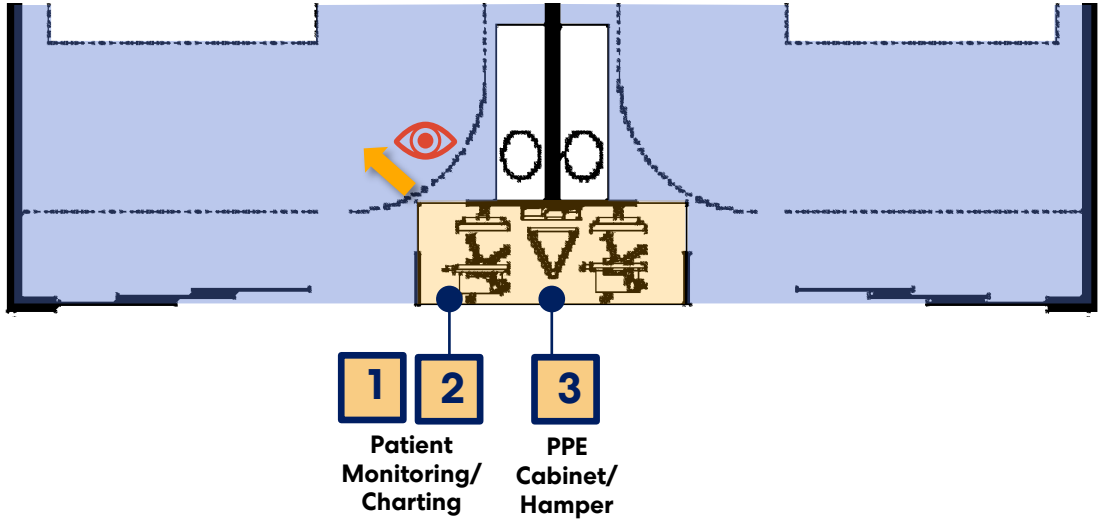
– Lynne Ingle

(#2 Provide Infection Control)
Take Monitors Out Of Rooms

(#1 Adapt the Way We Work)
Add Windows

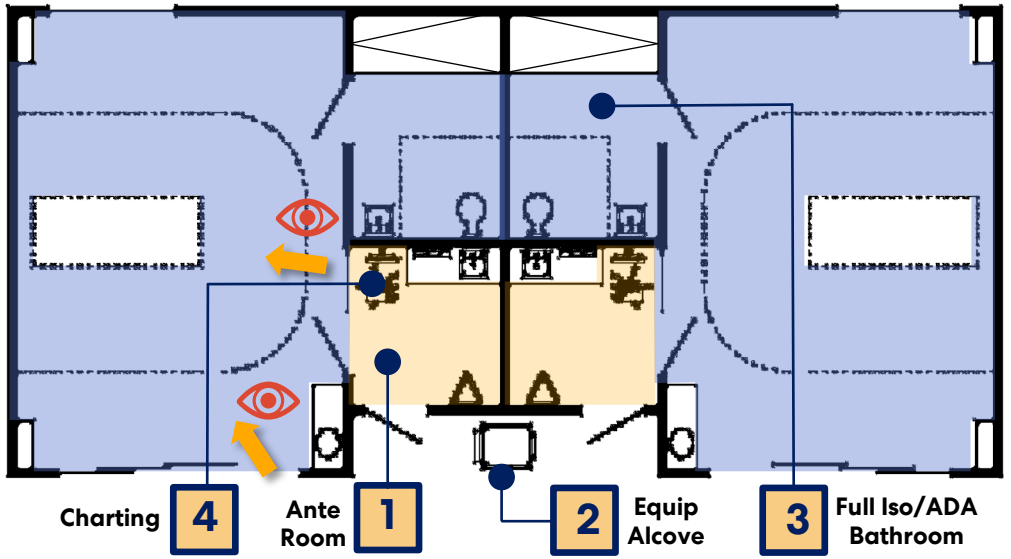
(#3 Increase Capacity)
Add More Isolation Rooms

ICU Room - Adaptations



Caregiver Substation Alcoves

"If there was a way to allow nurses to adjust alarms and settings without having to enter the room – if every time the patient bends their arm and the IV pole goes off because of a kink, they don't have to go into the room and waste an entire set of PPE just to lay the person's arm straight." *- Anthony Mistretta*



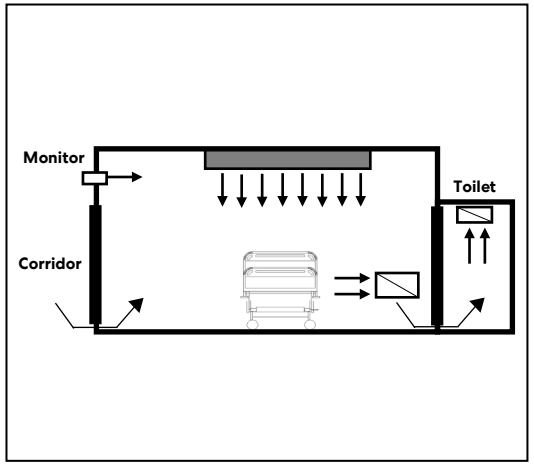
Optional Added Isolation Room(s)

"Ebola is a deadly disease. At one hospital we put two negative pressure rooms together (right off the triage area) with a door in-between them. With Ebola, the patient is highly contagious. You have to wear a special suit and bring down the bubble over the patient. If someone walked in and was experiencing what we thought was Ebola, we put the patient in one room and called the Ebola Team. They came down and donned in the other room and went through the door between the two rooms." *– Marvina Williams*

ICU Room - HVAC Solutions for A.I.I. Rooms

"If you have a patient that's in ICU with an endotracheal tube in while they're on a ventilator and it's there longer than two weeks, you really need to do a trach on that patient. As the ventilator works, the tube runs up and down in the airway. That tends to irritate the airway and cause scar tissue. In a pandemic, they might need to be done right in the room and that would be a source of aerosolization."

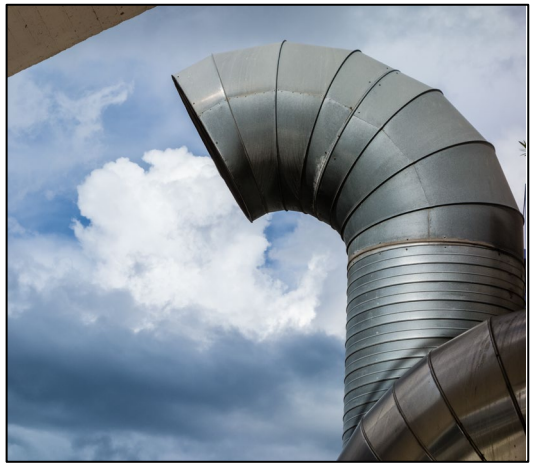
- Lynne Ingle



Susan Ealer

Air

- **Negative Air Pressure - 2.5PA**
- **Air Changes Per Hour (ACH) – 12**
- **Alarmed Air Pressure Monitor**
- **If An Ante Room is provided, air should flow from the corridor to the Ante Room and from the Ante Room to the All Room**



depositphotos

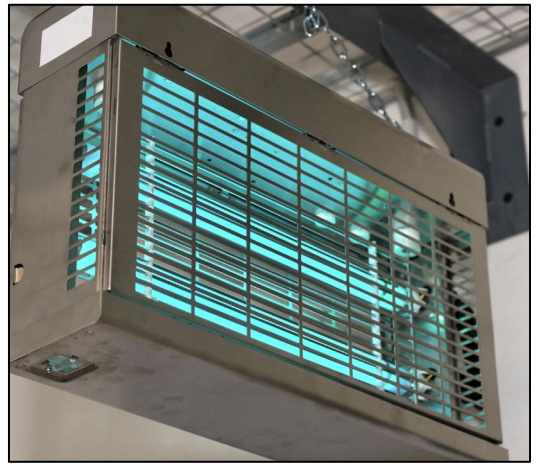
Exhaust

- **Exhaust must be discharged directly to the outside without mixing**
- **Exhaust Fan located outside away from intakes and public areas**

depositphotos

Filtration

- **Minimum-Efficiency Reporting Value (MERV) 7 pre-filters**
- **MERV 14 or High-Efficiency Particulate Air (HEPA) final filters**



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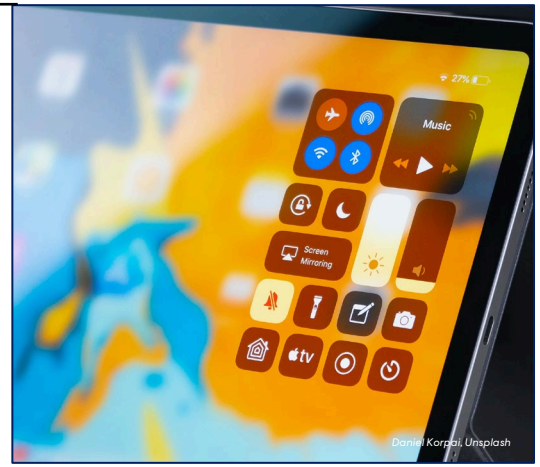
UV

- **Coil Sterilization or Air Sterilization**
- **Must be mounted next to the evaporator and on the downstream (cold air side) of the coil**
- **The UV rays must shine on the cooling coil and the water drain pan**
- **Designed to work in tandem with a particle filter**

ICU Room - Technology Solutions

"It is the patient's right to receive visits, therefore the risk of ARI (Airborne Respiratory Infection) transmission should be mitigated. "

- WHO Guidelines, Infection Prevention and Control of Epidemic and Pandemic Prone Respiratory Infections In Health Care

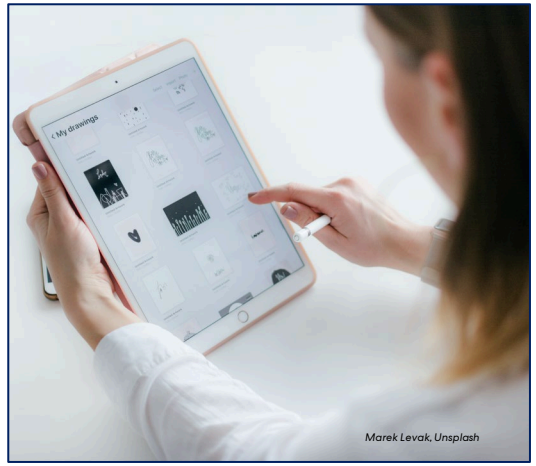


Patient Dashboard

"A major Southern California Hospital put the Microsoft Surface Hub in every ICU. It's like a big iPad you hang on the wall. They facilitate remote consults and family visits through that. People passing away alone - to me that's a massive failure of the system when we let that happen."

Remote Monitoring

"The next generation of cameras can not only give you an image of someone, they can tell you what their temperature is. This all means that staff can watch over their patients without having to physically go into the room itself."



Charting

"If you have to do bedside charting, you don't want the computer fixed to a wall by the bed in the ICU. Hospitals are looking at replacing those fixed units on walls with laptops or tablets. The problem there is that the majority of electronic medical records systems aren't really supported on a tablet."

UV Technology

"You can build it into the lights but there are also robots that can move around the room – a Roomba with a big UV light on it."

Hospital

‘We had a lot of meetings. There was a lot of meeting going on.’

- Department Director, major NYC hospital

Hospital

Testimonial:

The flow of patient traffic is very, very important. There's not much you can do about being in Manhattan and not having a lot of space to work with. If you have good patient flow in a small space, it really makes a lot of difference.

We now have patients enter through different entrances so that we don't have overcrowding at our main entrance. It seems like a good solution but then you have to take into consideration the fact that you need more screeners at more entrances and with more screeners you need more PPE. With more screeners it means those people volunteering are stepping out of their roles, whatever their roles were before, and we're not in a position to try and fill roles. With more screeners it also means you need more people volunteering to be frontline - interacting with thousands of people every day.

- ***Department Director, major NYC hospital***

"With each decision that is made, there are a lot of caveats that come with it."

- Department Director, major NYC hospital

Keeping The Hospital Healthy

Flow: although the ICU Unit is the focus of this study, the ICU Unit is not an island. Understanding it means understanding how it fits into the larger Hospital. Infectious Pandemic Surge Planning must take into account how staff, infectious patients, and supplies get in and get out. The safety of the patients and the staff in the Unit, as well as the safety of everyone they come into contact with inside the hospital, is dependent on creating flows that minimize the spread of disease from the minute they enter through the front door of the hospital building.

Operations: keeping the hospital healthy means keeping the hospital open. It's vital that we try and help these life-saving institutions stay as fully operational as possible during a Pandemic. Surgery is the life-blood of the institution and clinicians and planners are studying how to keep this department fully functional in an infectious environment.

Case Study: Preventing The Spread
New York City, COVID-19

Minimize Patients In The Hospital:

"Solutions to reduce the number of patients at one time in the hospital and allow for social distancing include: Preregistration, Just in time: Patients must be seen at the times of their appointments - no waiting, Telemedicine/E-ICU to help other facilities/locations." - recommendations from a major New York Hospital

Social Distancing:

"Being in Manhattan, one of the biggest challenges is that nobody is prepared for social distancing. In the height of the pandemic, when everything was so scary and so uncertain, it was almost easier than it is now. Once things started to return to the 'new normal' and we started seeing patients return, started seeing elective surgeries back on the schedule, nothing else changed in terms of what we needed to do to protect ourselves, our colleagues, and our patients but all of a sudden, we were getting volume back in our tiny Manhattan space. Being able to adapt and deliver care as we did before to, hopefully, close to the amount of people we were able to deliver it to before, while keeping everyone, patients and employees alike, safe and comfortable is a real challenge to this day." - Department Director, major New York City Hospital

Patient Transport:

"Every day policies are changing. People are more educated now. We can move COVID-19 positive patients through the hallways pretty safely. We send out a transport alert. Security clears the hallways. The transport elevator is cleared. We have on full PPE and the patient is wearing a mask." - Nurse treating COVID-19 patients

"Transporting infectious patients with proper PPE on, or with tenting if needed, through the usual hallways for short periods of time should be fine. Given the ventilation that we have and the PPE that we use it would not be an issue. Where it gets hairy, is when you are sharing air space with someone who is COVID positive for a long period of time." - Department Director, major New York City Hospital

Martin Sanchez, Unsplash

Hospital – Contributor Wish List

(#1 Adapt the Way We Work) Manage Infectious Patients

"Some recommendations are coming out suggesting totally separate entrances for the infectious and the non-infectious. I was thinking 'Well, wait a minute. You don't know who is infectious and who isn't. You're just letting the patient decide. We need to assume everyone is infectious."

– Marvina Williams

(#2 Increase Capacity) Add Waiting Room Space

"Chairs are 6'-0" apart with flip-down signs for the chair to be cleaned after each use. We use volunteers to monitor the area."

– Nurse treating COVID-19 patients

"100% - first on the list is Waiting Room space. The waiting and the flow are interrelated. If we had patients coming in one way and exiting on the other side, there would be less congestion and it would allow more people to wait."

- Department Director, major New York City Hospital

(#3 Provide Infection Control) Provide Isolation OR's

"We are talking with surgeons on one of our projects about setting up one of the OR's in a suite of 32 as an isolation OR."

- Chuck Siconolfi re: Nurse Anesthetist intubating patients in the ICU

"We bring patients mainly to the OR or to Imaging. An isolation OR would be really helpful."

– Nurse treating COVID-19 patients

(#1 Adapt the Way We Work)
Manage Infectious Patients

Anton, Unsplash

Assessor Station At Door

"Limiting the number of locations where people can come into the hospital while at the same time creating flexible greeter stations with quick-look nurses (or staff) allows for the separation of infectious and non-infectious patients. Anyone can safely enter without engaging or waiting with exposed patients." *- Marvina Williams*

Zane Lee, Unsplash

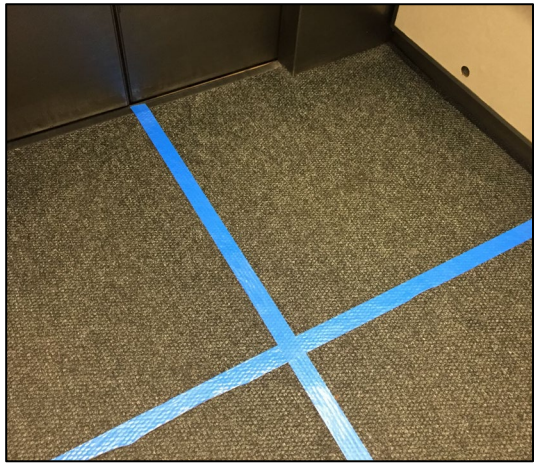
Provide Space Outside

"I helped plan a hospital which is set up for bio-terrorism and pandemics. We designed the ambulance bay sally port to allow suspected patients to be routed outside, tested and evaluated instead of letting them come inside the Main Lobby." *- Marvina Williams*

Mfud Majnun, Unsplash

Safe Patient Transport

"We put a mask on them. The staff are wearing masks. We use back-of house corridors and elevators. The patients don't touch anything in the elevators. They're not in the elevator very long so exposure is limited. Hospitals are already pretty much set up to limit the spread. *– Nurse treating COVID-19 patients*



Susan Ealer

Ventilate Elevators

"Elevators have little or no air circulation. No air sanitization is employed at all. It is important to provide proper, continual, balanced circulation, removing contaminated air and replacing it with filtered sanitized air utilizing high efficiency filtering and UV-C irradiation." *– Elevator Cab Purification System Representative*

(#2 Increase Capacity)
Add Waiting Room Space

Macau Photo Agency, Unsplash

One-Way Flow

"The waiting and the flow are interrelated. If we had patients coming in one way and exiting on the other side, there would be less congestion and it would allow more people to wait." *- Department Director, major New York City Hospital*

Susan Ealer

Separation

"In the ED's, we're talking about separation **of waiting rooms so the person who comes in with a sprained foot isn't sitting next to someone who is coughing.** ***Or putting infectious patients on one side of the room separating them with plexiglass."*** *- Marvina Williams*

Macau Photo Agency, Unsplash

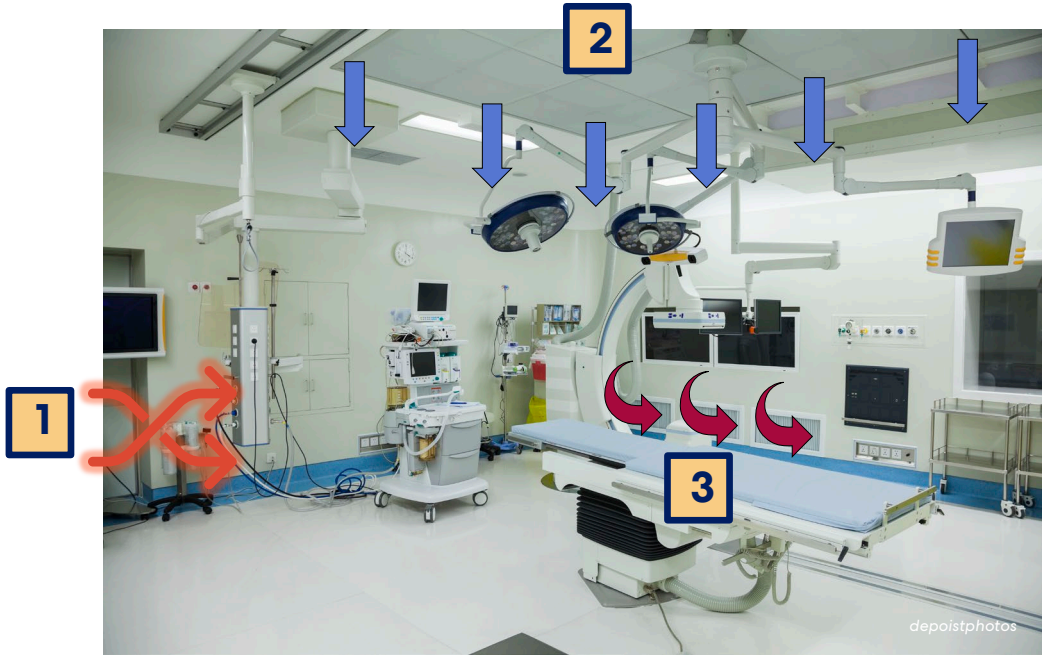
Limiting Numbers

"Lots of front-line staff feel like the waiting is a problem. It clearly is because they are trying to introduce social distancing. There are two things that should be added to the discussion. Limiting the number of people in the hospital (i.e. just in time, telemedicine) The other thing is the ventilation." *- Chuck Siconolfi*

Provide for Visitors

"I'm working with a large trauma center client right now. We talked about designing a temporary building outside the hospital for visitors. So many places are making the visitors wait in their cars. It's cold or it's hot. There are no bathrooms in the parking lot." *- Marvina Williams*

(#3 Provide Infection Control)
Provide Isolation OR's



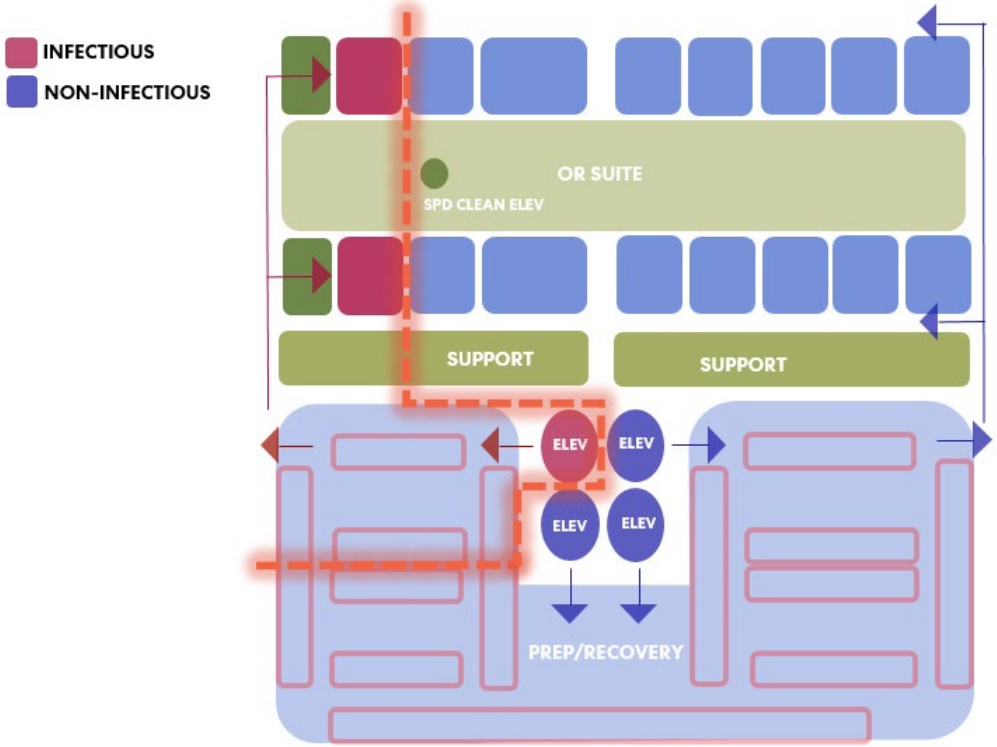
Isolation OR Diagram

(Negative Pressure, Dedicated HVAC)

1 **Airtight/interlocking doors from Ante Room**

2 **Laminar airflow/HEPA filters/outside air supply**

3 **Low wall registers-high velocity/HEPA filters/exhaust to exterior**



Flow From ICU to Isolation OR

(Dedicated: Elevator, Prep/Recovery, & 2 Isolation OR's)

"Nobody wants to shut down surgery. (During the 2020 COVID-19 Surge) they did and they are dying (financially) because of it." *- Marvina Williams*

Case Study: Minimizing Supply-Chain Shortages

New York City, COVID-19

"For better or worse, the supply chain difficulties experienced by the COVID-19 response have raised awareness of the critical importance of an effective supply chain. Reliable supplies of test-kits, equipment, pharmaceuticals, and PPE are essential to a continuous, successful response." – Sean O'Neil, Executive Vice President, St. Onge Company (multiple quotes this page)

Consolidated Service Center:

"The current operational approach focuses on a just-in-time model, where hospitals and health systems rely heavily on their distributor(s) for daily deliveries of primary medical and surgical supplies. A recent trend has created the same capability through a system-owned Consolidated Service Center."

Manufacturers	Resupply Source	Secondary Source	Primary Source (Unit/Bedside)
Supplier Base	Local Hospital Storeroom	Clinical Unit Supply Rooms	Point-of-Use Carts, Servers
	Low Unit-of-Measure • Distributor-managed • Hospital-managed	STAT Storeroom	• Clinical Unit Supply Rooms • Point-of-Use Carts • Nurse Servers
	Consolidated Service Center • Distributor-managed • Hospital-managed	STAT Storeroom	• Clinical Unit Supply Rooms • Point-of-Use Carts • Nurse Servers

Avoid Reacting – Plan The Response:

"We must work with the hospital team to ensure there is not an overreaction to store significant inventory on site (at a potential loss of revenue generating space). Someone in leadership might declare, 'We need to stockpile 90 days of supplies.' Teams. need to develop a pandemic inventory response strategy that incorporates the upstream supply chain capability, product shelf life, expiration, stock rotation and available space to determine the resulting pandemic response inventory position at an item level. Mitigation plans should evaluate off-site or contracted disaster response inventory and consider reusable and sterilized product options."

John Cameron, Unsplash

Hospital - Technology Solutions

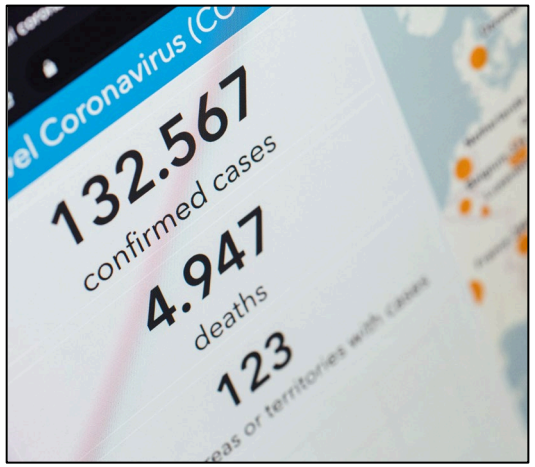
"Some people call technologic devices 'toys.' These can be expensive devices and, until you deploy them properly, they kind of are toys. It's all about the workflow, understanding where the danger points are, and using a technology that can reduce the risk or replace that part of the workflow with something else."

- Phil Crompton, *Vantage Technology Consulting Group*

Annie Spratt, Unsplash

Drones

"You could deliver a surgical tray with a drone quite easily. Since the drone can't fly inside the hospital, I assume it would be a roof-based thing like the heli-pad."



Marcus Spiske, Unsplash

Contact Tracing

"If you badge everybody and it turns out someone does have COVID we can do contact tracing. You can see everyone they have come into contact with using an RTLS badging system. They call it breadcrumbs. You can follow their tracks."

Nathan Dumlao, Unsplash

Touchless

"There's lots of touchless things we can do. That just needs to be standard design full-stop in my mind. We should never have another press-plate in a hospital. Now, we can just wave our hands in front of them and they do the same thing."

Wikipedia

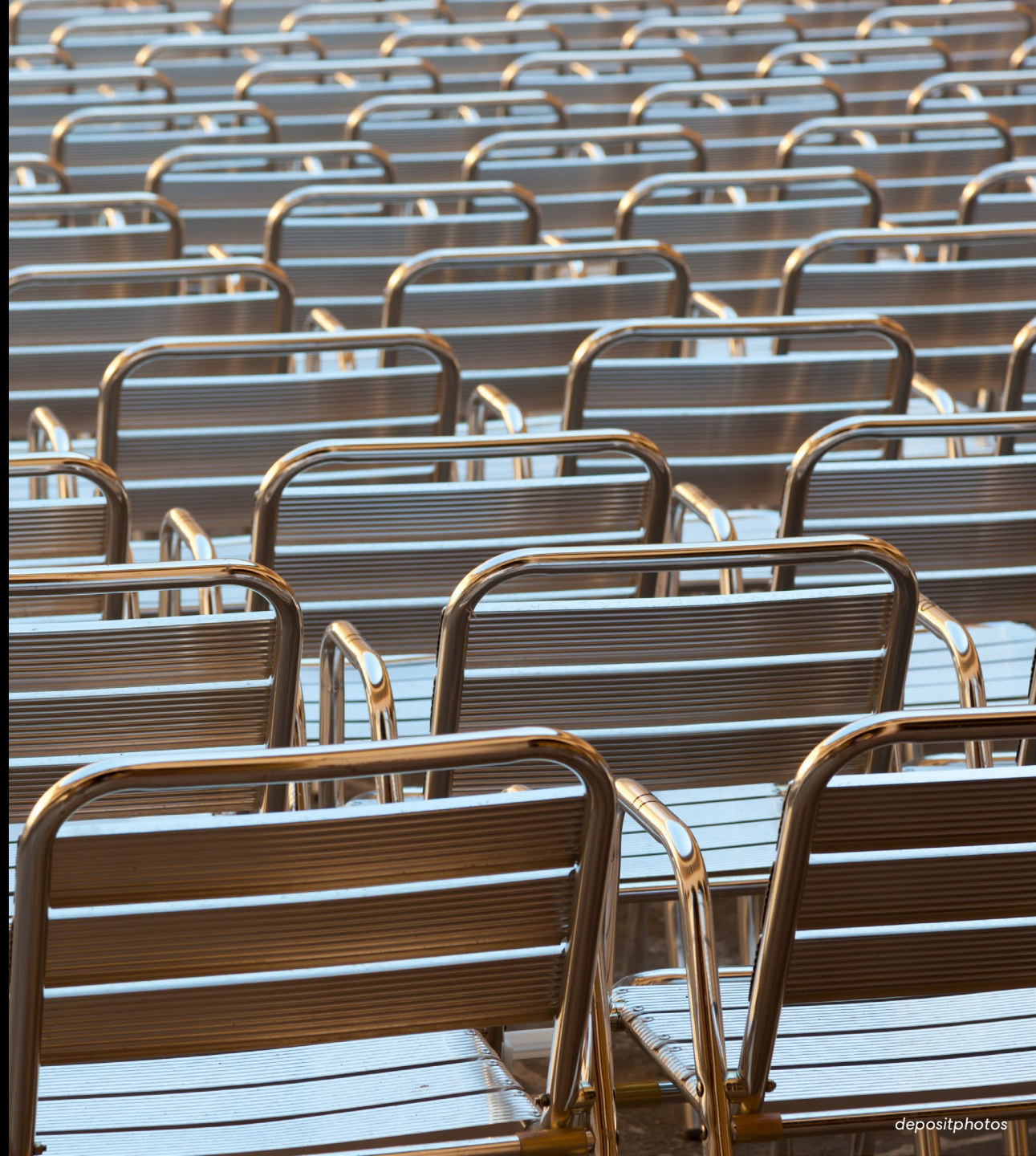
Thermal Cameras

"Thermal cameras can be placed at staff and patient entrances to detect elevated skin temperature."

Space Program

‘The COVID-19 pandemic is an event that is unique in human history. Developing a program to help people respond is important.’

- Chuck Siconolfi, Regional Director, Principal, Perkins&Will



Space Program

Testimonial:

It's early June, Phase 1 Re-Opening in Manhattan. I'm driving in from Westchester for physical therapy. If I hadn't shattered my arm before the surge I would not be here but I can't blow this off. I reach that moment when I can finally see the skyline and, instead of getting that usual little beat of excitement from the sheer enormity of it, I suddenly have a knot in the pit of my stomach. I haven't set foot here since 20,000 people died. Sure I had COVID, but immunity isn't guaranteed.

As I reach the FDR expressway, I have my windows rolled-up tight. Can COVID hitchhike on air flowing through the city streets and leak in? I don't know. So many things I've been told about COVID have been proven wrong at this point. I don't believe anyone knows. As I reach Exit 13 for 71st St, I realize I'm going to valet my car and I need to put on my mask. Do I put it on now? Do I wait until I get there? I haven't been wearing a mask this whole time so the air in my car is contaminated. Was I supposed to? What is the protocol here?

At this point, I'm pretty stressed out but it's not until I get out of the car and find myself in front of the door to the elevator lobby with a handle that I'm going to have to TOUCH to open that I realize I am REALLY not prepared for this and I'm going to have to seriously figure some things out or I'll be in big trouble...

- Author, COVID-19 patient

"A voice inside my head just kept screaming, "Don't touch anything!"

- Author, COVID-19 patient

Space Program:

To ensure the highest standard of Baseline Critical Care is incorporated, the following Infectious Pandemic Surge Space Program was developed using a Perkins&Will Traditional best practice ICU Unit Space Program as it's foundation (created by Jeff Dreesman, Perkins&Will).

Space Program
Meeting The Need

Defining The Need

The research documented in this article began with the desire to identify a need. This led to conversations and interviews with front-line workers, designers, strategists, and various experts. It continued with synthesis, analysis, and formulation of design strategies.

Simply put, the need identified through this effort is for an ICU that is designed to be prepared to respond to an infectious pandemic and is reasonable (financially, operationally) for hospitals and systems to build (or adapt).

Meeting The Need

Meeting the overall need in a way that hospitals can afford and operate means leveraging the assets provided in a traditional ICU Unit design to allow the Unit to flex in times of infectious pandemic surge. This means that many of the components that make up the regular ICU will have dual-functions.

Some Examples of this strategy are:

- **Flexing:** rooms that will not be used during a pandemic, (i.e., waiting rooms, patient education (multipurpose in California), consultation), will be used for needed pandemic **functions such as: additional storage, work, and respite areas.**
- **Smoke Barriers:** will double as infection control barriers when flexing a unit for Isolation. Dedicated support instead of support shared between units is required in this configuration.
- **Work Areas:** will be configured for maximum efficiency, flexibility, and expandability and to keep staff safe in day-to-day as well as infectious pandemic surge circumstances.

Infectious Pandemic Surge ICU Unit Program (Flex Isolation)

Change from Traditional Program to Allow For Unit to Flex to Pandemic Surge Condition

Intensive Care Unit 12 Bed Unit	Traditional Unit Quantity	Traditional Unit NSF/Room	Total NSF	Pandemic Surge Quantity	Pandemic Surge NSF/Room	Total NSF	Comments
Patient Care							
Patient Room, Private	11	300	**3,300**	10	300	**3,000**	Optional - Provide Bariatric Room
Patient Toilet	11	40	**440**	10	40	**400**	
Patient Toilet (Accessible)	0	60	**0**	0	60	**0**	ADA toilet provided in Isolation
Patient Room, Isolation	1	300	**300**	2	300	**600**	
Patient Toilet, Iso (Accessible)	1	50	**50**	2	50	**100**	Optional additional Isolation Room for use during smaller outbreaks.
Ante Room	1	60	**60**	2	60	**120**	
Gurney Shower Room	1	80	**80**	1	80	**80**	
Caregiver Substations	5	15	**75**	5	24	**120**	Between every 2 Patient Rooms,
PPE Cabinet	5	2	**10**	5	2	**10**	
Multipurpose Room	1	180	**180**	1	180	**180**	Can be outside the Unit. Flex for Central Pandemic Storage, Work or Respite.
Patient Toilet	1	40	**40**	1	40	**40**	
Sub-Total NSF			**4,535**			**4,650**	
Patient Care Support							
Unit Ante Room	0	0	**0**	1	90	**90**	Corridor space not included in
Handwashing Station	0	0	**0**	1	10		
PPE Cabinet	0	0	**0**	1	2		
Caregiver Station	2	180	**360**	3	170	**510**	
Handwashing Station	2	10		4	10		
Pneumatic Tube Station	1	10		1	10		
Point of Care Testing	1	10		1	10		
Crash Cart Alcove	2	10		3	10		
Workstations	12	10		12	18		Pandemic Surge NSF incorproates social distancing.
Printer/Copier Alcove	2	15		3			
Clean Supply Room	1	160	**160**	1	195	**195**	
Alcove, Clean Linen	1	30	**30**	1	30	**30**	
Soiled Utility Room	1	120	**120**	1	175	**175**	
Medication Room	1	120	**120**	1	150	**150**	
Nourishment Room	1	100	**100**	1	100	**100**	
Storage Room, Equipment	1	240	**240**	1	300	**300**	
St	1	80	**80**	1	100	**100**	
Alcove, Imaging Equipment	1	30	**30**	1	30	**30**	
Wheelchair/Stretcher Storage	1	15	**15**	1	15	**15**	
Housekeeping Room	1	60	**60**	1	80	**80**	
Sub-Total NSF			**1,315**			**1,775**	
Staff Support							
Staff Lounge	1	240	240	1	240	**240**	Exterior terrace space not
Staff Lockers	1	40	40	1	40	**40**	
Staff Toilet	2	50	100	2	50	**100**	
Workroom, Care Team	2	180	360	2	225	**450**	
On-Call Room	1	80	80	1	80	**80**	Can be outside the Unit.
Staff Toilet/Shower	1	80	80	1	80	**80**	Can be outside the Unit.
Offices	2	100	200	2	100	**200**	
Quiet Room, Staff	1	100	100	1	100	**100**	
Quiet Room, Lactation	1	100	100	1	100	**100**	
Sub-Total NSF			**1,300**			**1,390**	

Space Program
Meeting The Need

- **Patient Room Headwalls and Booms:** will be situated to allow two patients in one room without impacting day-to-day workflow. Rather than doubling-up on these expensive services, additional outlets will be added to augment capacity.

Space Program

To ensure the highest standard of baseline critical care is incorporated, the following Infectious Pandemic Surge ICU Space Program was developed using a Traditional Best Practice ICU Space Program as its foundation

The infectious pandemic surge elements outlined in this paper are incorporated into the program. Special consideration has been given to the grossing factors to prevent added square footage from making the solution unaffordable for healthcare systems.

- **Departmental Gross Square Footage:** Applying a standard ICU grossing factor of 1.6 to the overall net square footage of the Infectious Pandemic Surge ICU Program (8,465 SF) yields 13,544 Departmental Gross Square Footage – a modest increase of eight percent (1,064 DGSF) over the 12,480 DGSF Traditional Program.

- **DGSF Per Key Planning Unit:** The Infectious Pandemic Surge ICU Program results in 1,129 DGSF per patient room vs. the Traditional Program at 1,040 DGSF. It is slightly above industry recommendations, which fall between 800 DGSF and 1,100 DGSF.

Format

The Infectious Pandemic Surge ICU Program is represented side-by side with the Traditional Program and the resulting additional SF investment is calculated. Infectious Pandemic Surge Program elements that differ from the Traditional Program are highlighted in yellow.

Infectious Pandemic Surge ICU Unit Program (Flex Isolation)

Change from Traditional Program to Allow For Unit to Flex to Pandemic Surge Condition

Intensive Care Unit 12 Bed Unit	Traditional Unit Quantity	Traditional Unit NSF/Room	Total NSF	Pandemic Surge Quantity	Pandemic Surge NSF/Room	Total NSF	Comments
Public Areas							
Family Waiting	12	20	240	12	20	**240**	Calculated using NSF per seat. Outside the Unit. No waiting during Pandemic. Flex for Work or Respite.
Resource/Patient Education	1	60	60	1	60	**60**	Outside the Unit. No outside consultation during Pandemic. Flex for Work or Respite.
Consultation Room	1	120	120	1	120	**120**	
Toilet, Male	1	80	80	1	80	**80**	
Toilet, Female	1	80	80	1	80	**80**	
Fountain, Drinking	1	15	15	1	15	**15**	
Phone, Public	1	15	15	1	15	**15**	
Vending Alcove	1	40	40	1	40	**40**	
Sub-Total NSF			**650**			**650**	
Total NSF			**7,800**			**8,465**	
DGSF Multiplier			1.60			**1.60**	Additional mechanical space for dedicated Isolation Unit HVAC not included in DGSF.
Total DGSF (Delta = + 8% DGSF)			**12,480**			**13,544**	**1,064**
DGSF/Key Room			**1,040**			**1,129**	Standard Range: 850-1100 SF/Bed

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