Four decades of ICU design evolution with a peak into the future

Neil A Halpern MD, MCCM, FCCP, FACP
Director, Critical Care Center
Memorial Sloan Kettering Cancer Center, NYC

Agenda

- Transitions
- Hospital & ICUs
- Patient rooms
- Informatics
- Staffing
- POCT
- Models of care
- COVID 19
- Sustainability
- 1984 vs 2022
- Future proofing

CHEST Postgraduate Education Corner
CONTEMPORARY REVIEWS IN CRITICAL CARE MEDICINE

Innovative Designs for the Smart ICU

Part 1: From Initial Thoughts to Occupancy

Neil A. Halpern, MD, FCCP

Designing a smart ICU is a time-consuming, complex, multiphased, politi
This process begins with two notions: First, all hospital parties agree that a
is required, and second, the hospital has agreed to allocate space, personn
for the project. In this first of a three-part series on innovative designs for
explore the roles of the ICU design team in managing the design process. Th
istratively empowered, knowledgeable, and forward thinking. The first cha
is to develop a clear vision for the goals, look and feel, and functionalit
vision must be guided by the imperative to positively impact patients, staff,
must concentrate on innovative but practical ideas that are in compliance v
design guidelines and address issues related to renovation vs new constr
physical and computer generated, and a simulation laboratory for advanc
be used to test design assumptions and reveal problems well in advance
tion and technology implementation. Technology platforms need to be s
ICU and equipment purchases protected against early obsolescence. The r
tations of the new ICU must be thoughtfully considered and dealt with dur
Last, it is essential that the design group continue its involvement in the
struction, occupancy, and post occupancy. *CHEST*

Abbreviation: CCM = critical care medicine

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Informatics for the Modern Intensive Care Unit

Diana C. Anderson, MD, M Arch; Ashley A. Jackson, BS; Neil A. Halpern, MD, MCCM, FACP, FCCP

Advanced informatics systems can help improve health care delivery and the environment of care for critically ill patients. However, identifying, testing, and deploying advanced informatics systems can be quite challenging. These processes often require involvement from a collaborative group of health care professionals of varied disciplines with knowledge of the complexities related to designing the modern and "smart" intensive care unit (ICU). In this article, we explore the connectivity environment within the ICU, middleware technologies to address a host of patient care initiatives, and the core informatics concepts necessary for both the design and implementation of advanced informatics systems. **Key words:** *informatics systems*, *middleware*, *patient safety*, *staff efficiency*

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Innovative Designs for the Smart ICU

Part 2: The ICU

Neil A. Halpern, MD, FCCP

Successfully designing a new ICU requires clarity of vision and purpose and the recognition that the patient room is the core of the ICU experience for patients, staff, and visitors. The ICU can be conceptualized into three components: the patient room, central areas, and universal support services. Each patient room should be designed for single patient use and be similarly configured and equipped. The design of the room should focus upon functionality, ease of use, healing, safety, infection control, communications, and connectivity. All aspects of the room, including its infrastructure; zones for work, care, and visiting; environment, medical devices, and approaches to privacy; logistics; and waste management, are important elements in the design process. Since most medical devices used at the ICU bedside are really sophisticated computers, the ICU needs to be capable of supporting the full scope of medical informatics. The patient rooms, the central ICU areas (central stations, corridors, supply rooms, pharmacy, laboratory, staff lounge, visitor waiting room, on-call suite, conference rooms, and offices), and the universal support services (infection prevention, finishings and flooring, staff communications, signage and wayfinding, secu-
terwoven. This coordination helps establish effi-
osters physical and social cohesiveness within the
centralized monitoring and logistics also offers
pport services in the ICU with the hospital's exist-
uity across the enterprise and avoids unnecessary
CHEST 2014; 145(3):646–658

t-of-care testing; RTLS = real-tir

Intensive Care Med (2017) 43:690–692
DOI 10.1007/s00134-017-4728-x

WHAT'S NEW IN INTENSIVE CARE

ICU design in 2050: looking into the crystal ball!

Neil A. Halpern[1,2,5*], Diana C. Anderson[3] and Jozef Kesecioglu[4]

CHEST Postgraduate Education Corner
CONTEMPORARY REVIEWS IN CRITICAL CARE MEDICINE

Innovative Designs for the Smart ICU

Part 3: Advanced ICU Informatics

Neil A. Halpern, MD, FCCP

This third and final installment of this series on innovative designs for the smart ICU addresses the steps involved in conceptualizing, actualizing, using, and maintaining the advanced ICU informatics infrastructure and systems. The smart ICU comprehensively and electronically integrates the patient in the ICU with all aspects of care, displays data in a variety of formats, converts data to actionable information, uses data proactively to enhance patient safety, and monitors the ICU environment to facilitate patient care and ICU management. The keys to success in this complex informatics design process include an understanding of advanced informatics concepts, sophisticated planning, installation of a robust infrastructure capable of both connectivity and interoperability, and implementation of middleware solutions that provide value. Although new technologies commonly appear compelling, they are also complicated and challenging to incorporate within existing or evolving hospital informatics systems. Therefore, careful analysis, deliberate testing, and a phased approach to the implementation of innovative technologies are necessary to achieve the multilevel solutions of the smart ICU. *CHEST 2014; 145(4):903–912*

Abbreviations: Auto-ID = automatic identification; EMR = electronic medical record; FDA = US Food and Drug

Four Decades of Intensive Care Unit Design Evolution and Thoughts for the Future

Neil A. Halpern, MD, MCCM, FCCP, FACP[a,b,*],
Elizabeth Scruth, PhD, MPH, RN, CNS, CCRN-K, CCNS, FCCM, FCNS, CPHQ[c],
Michelle Rausen, MS, RRT, RRT-NPS[d], Diana Anderson, MD, MArch[e]

Crit Care Clin ■ (2023) ■–■
https://doi.org/10.1016/j.ccc.2023.01.008

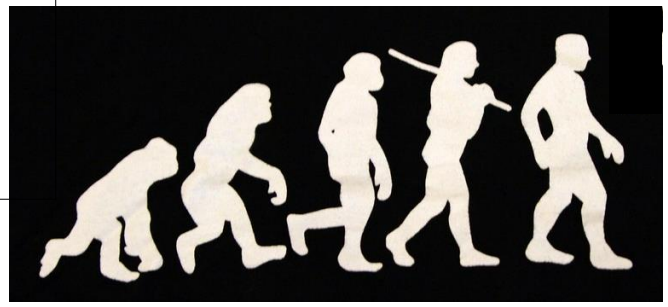
How many ICUs are we talking about in US?

- 3000 acute care hospitals
  - 2-3 ICUs/Hospital
- 6000-9000 ICUs
  - 100,000 ICU beds
- Larger hospitals more ICUs than smaller hospitals
- Not possible to determine number of renovated or newly built ICUs

From Here to There and There Again

There (1980s)

- Iterative
- Transformative
- Slow Change
- Cannot pinpoint inflection point
- Seems like evolution



Here (2020s)

There (2030s)

- Prophesy
- Foresight
- Tea Leaves
- Tarot Cards
- Future proofing
- AI

Transition: Informing ICU design: 1950s-1980s

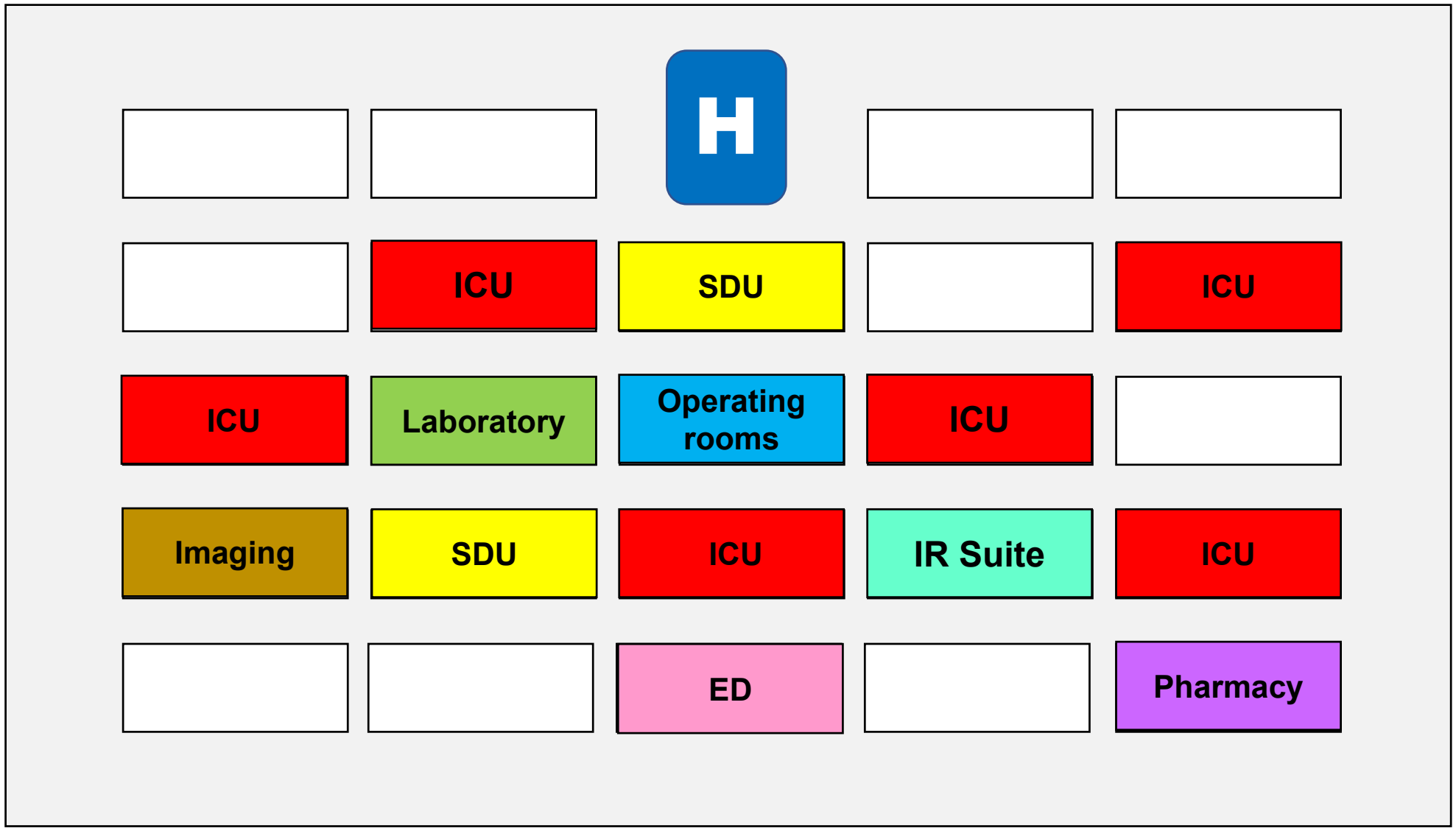
- Dearth of information
- Architects & Intensivists- minimal experiences
- Physical drawings
- Physical mock-up
- Renovate in old spaces

Transition: Informing ICU design – Today

- SCCM website outstanding designs - 30yrs of awards
- Evidence based design literature
- Experienced designers, ICU architects, intensivists
- Strategic thinking
- Capacity modelling
- Guidelines (SCCM, US-FGI and international)
- Electronic displays
- 3D configurations
- AI design

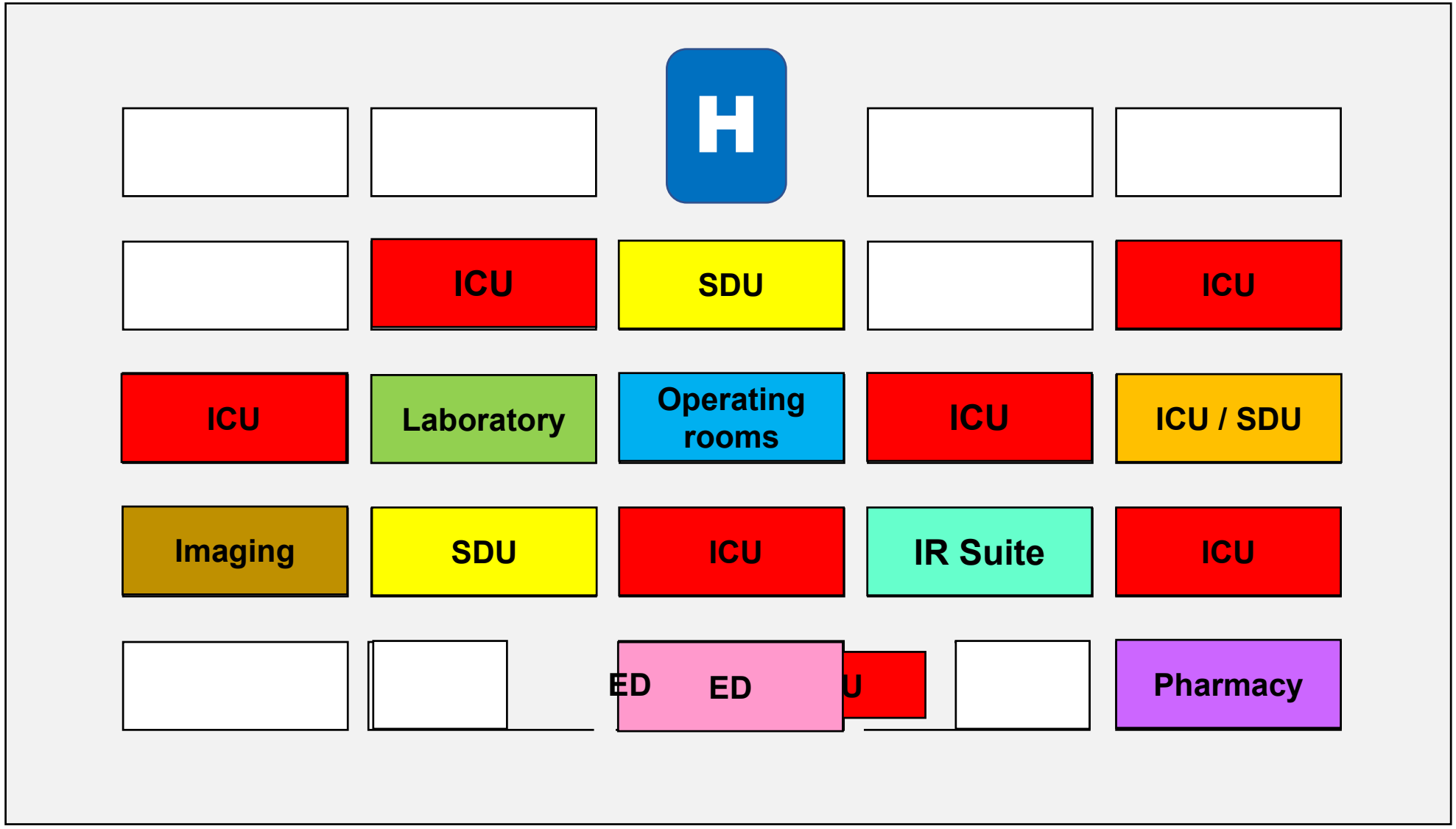
Transition: Who participates in ICU design ?

- 1950s-1980s
  - Hospital administrators
  - Architects
- 1980s-2010
  - Broad based – Inclusive of users
    - Nurses
    - Intensivists
- Now - large pavilions
  - Hospital administrators
  - Architects
  - Hopefully, ICU team members


H
ICU
SDU
ICU
ICU
Laboratory
Operating rooms
ICU
Imaging
SDU
ICU
IR Suite
ICU
ED
Pharmacy

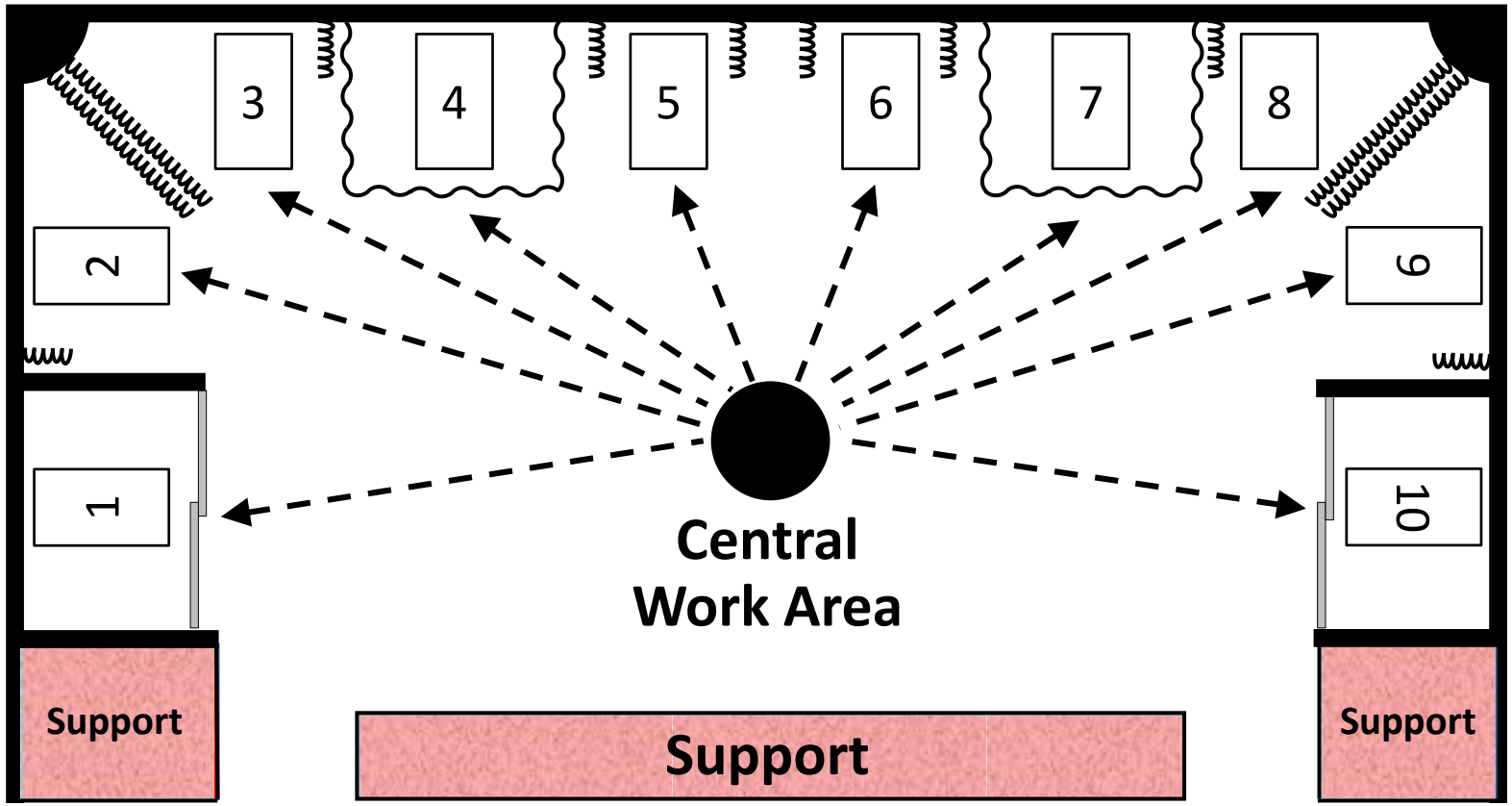
ICU transitions: Where are ICUs positioned?

- 1970s-1980s – Older hospitals
  - Build or renovate ICUs & SDUs wherever space is available
  - No attention to economies of scale
  - No consideration of hospital supporting the ICU
  - No consideration of ICU supporting the hospital


H
ICU
SDU
ICU
ICU
Laboratory
Operating rooms
ICU
ICU / SDU
Imaging
SDU
ICU
IR Suite
ICU
ED
ED
U
Pharmacy

ICU transitions: Where are ICUs positioned?

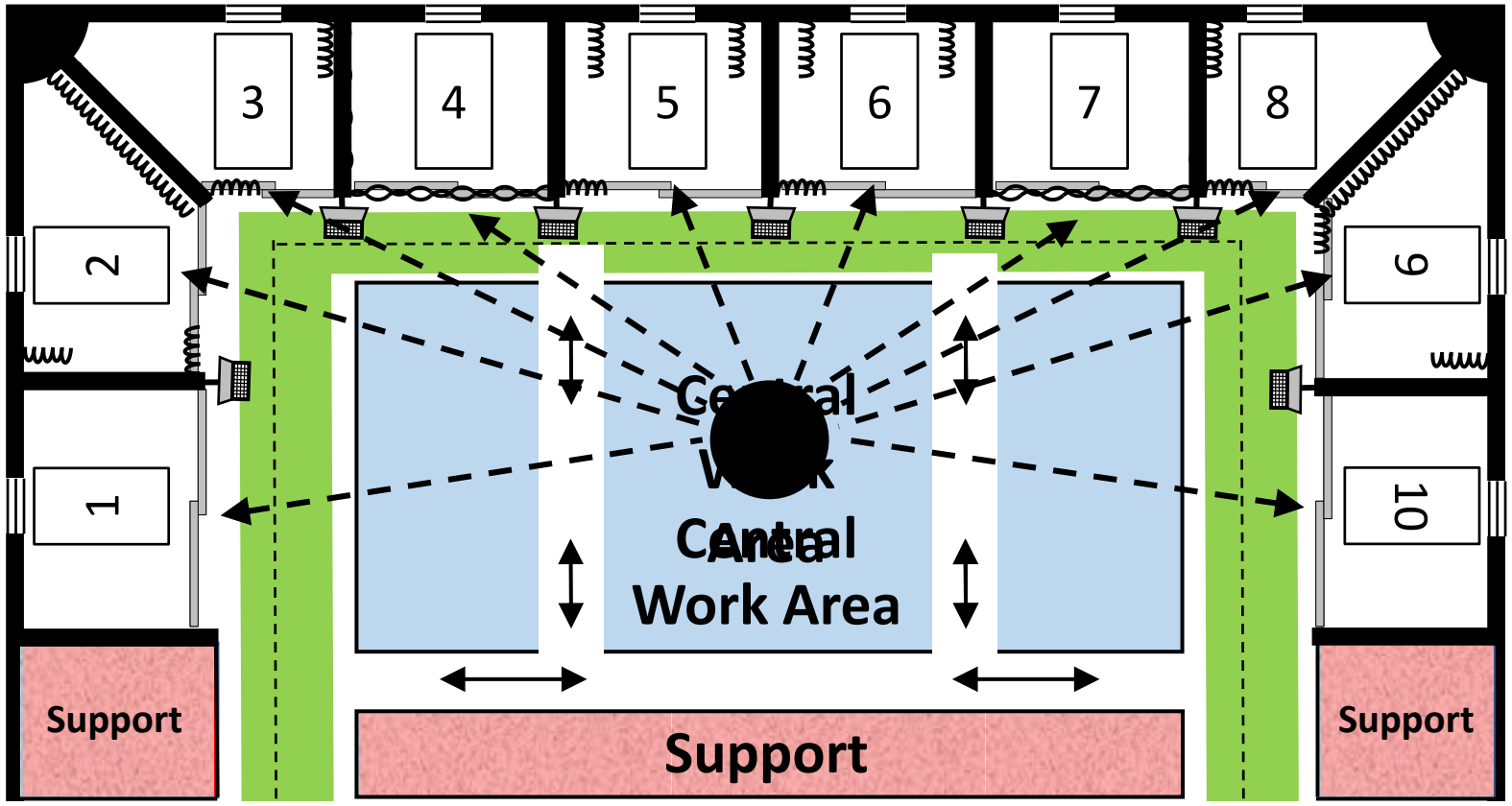
- 2000 to date - Acute care pavilions
  - Purposeful ICU location
  - Co-locate ICUs (same floors, stacked)
  - Economies of scale
  - Locate supporting facilities
    - Support ICU (Pharmacy, Lab, RT, Imaging)
    - ICU supports other spaces (OR/PACU)


3
4
5
6
7
8
2
9
1
10
Central
Work Area
Support
Support
Support

The ICU themselves: 1960s-1980s

- Open bay, multi-patient, no corridors
  - Gen 1: Combine multi bed rooms to form ICUs
  - Gen 2: Construct large open space ICUs with some isolation rooms

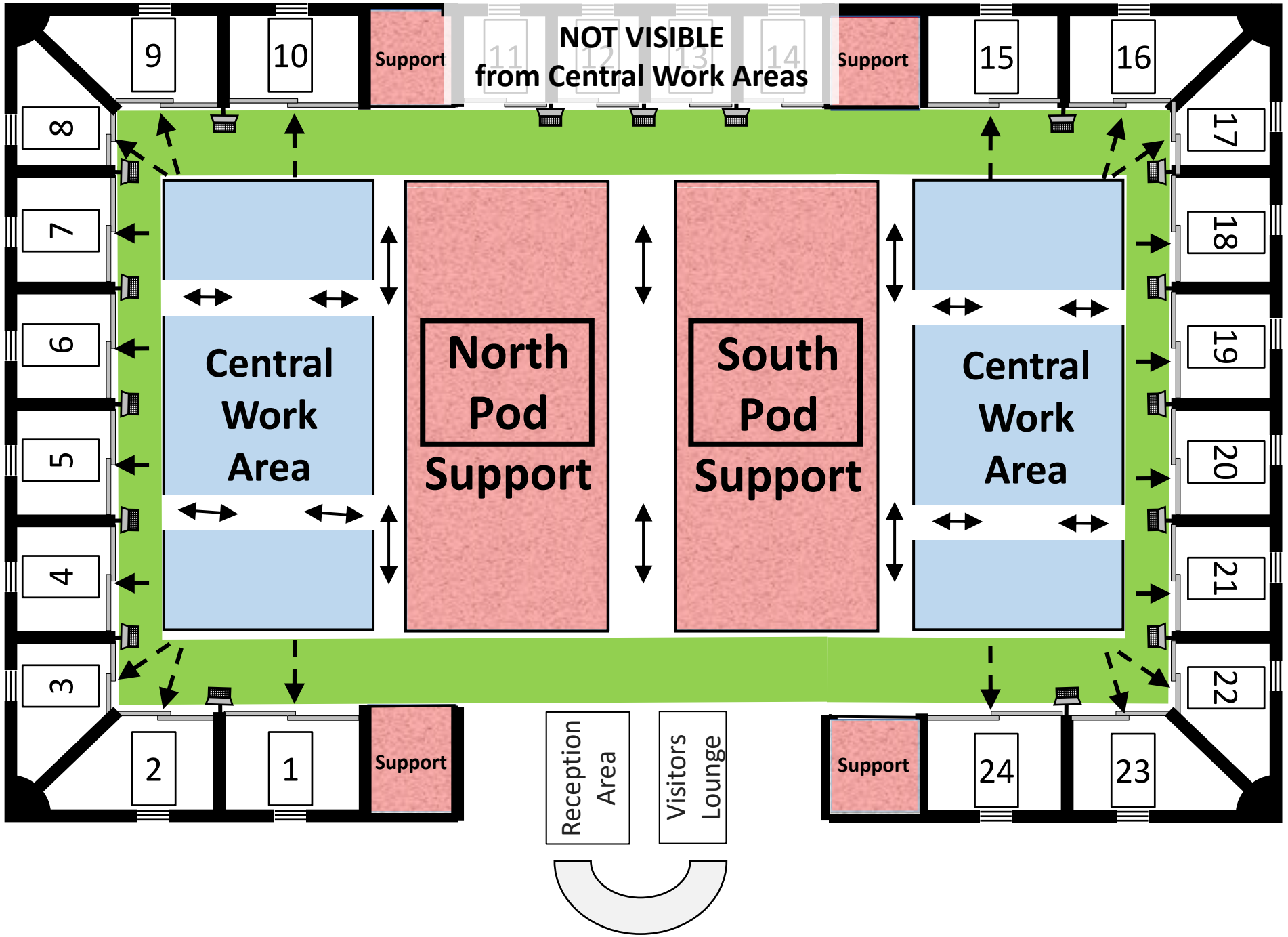
The good
Visibility maximized
Resources rapidly deployed
Patient space (Room) can stretch
See visitors to arrange meetings


3
4
5
6
7
8
2
9
1
10
Central Work Area
Support
Support
Support

The ICU themselves: 1990s forward

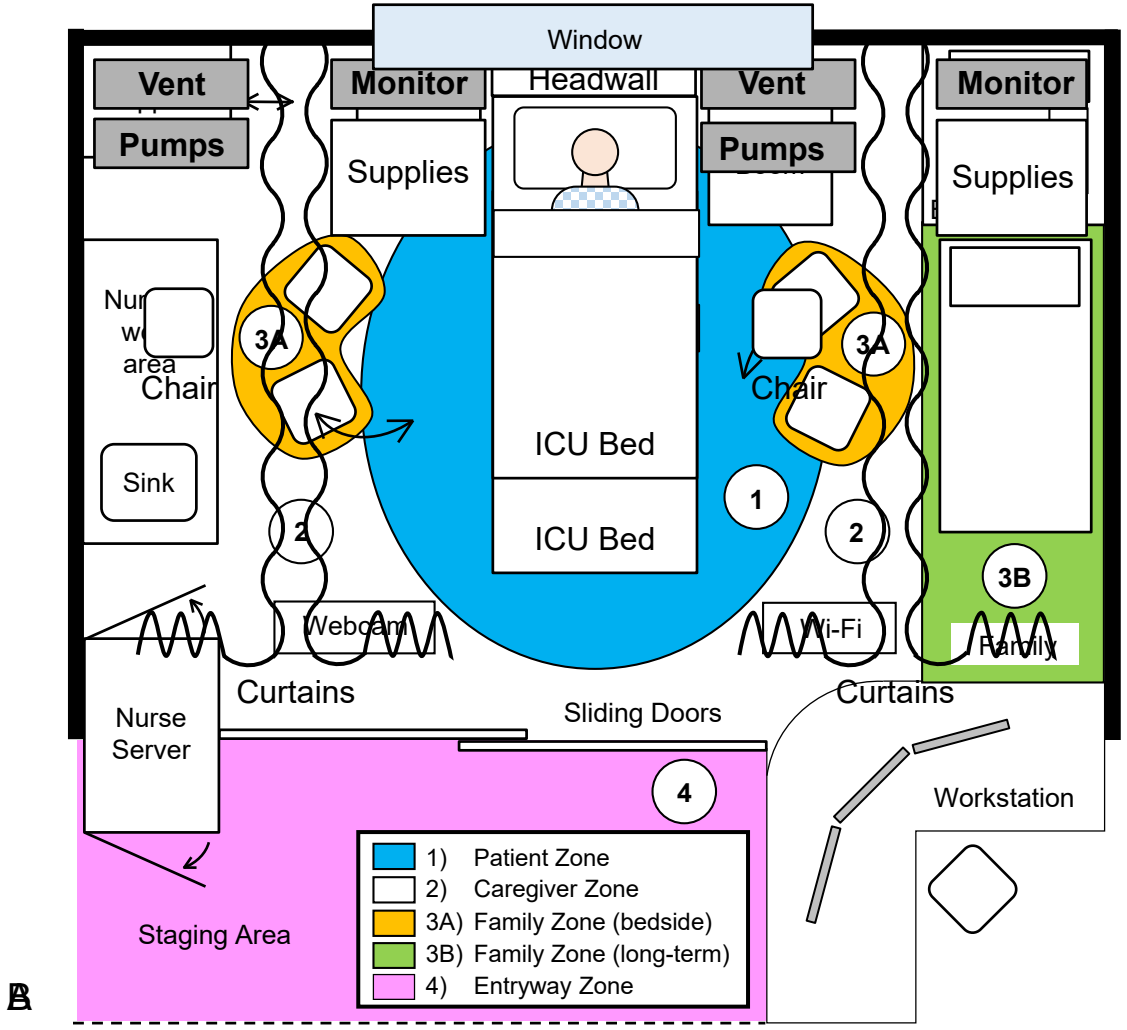
- Open bay, multi-patient & no corridors to SINGLE rooms & corridors

The good
Excellent privacy
Room based Infection control
Environmental control
Windows/ ambient light
Sinks, toilets, CRRT/HD plumbing
Local computers
Local entertainment
Builds out corridors


9
10
Support
11
12
13
14
NOT VISIBLE
from Central Work Areas
Support
15
16
8
7
6
5
4
3
17
18
19
20
21
22
Central
Work
Area
North
Pod
Support
South
Pod
Support
Central
Work
Area
2
1
Support
Reception
Area
Visitors
Lounge
Support
24
23

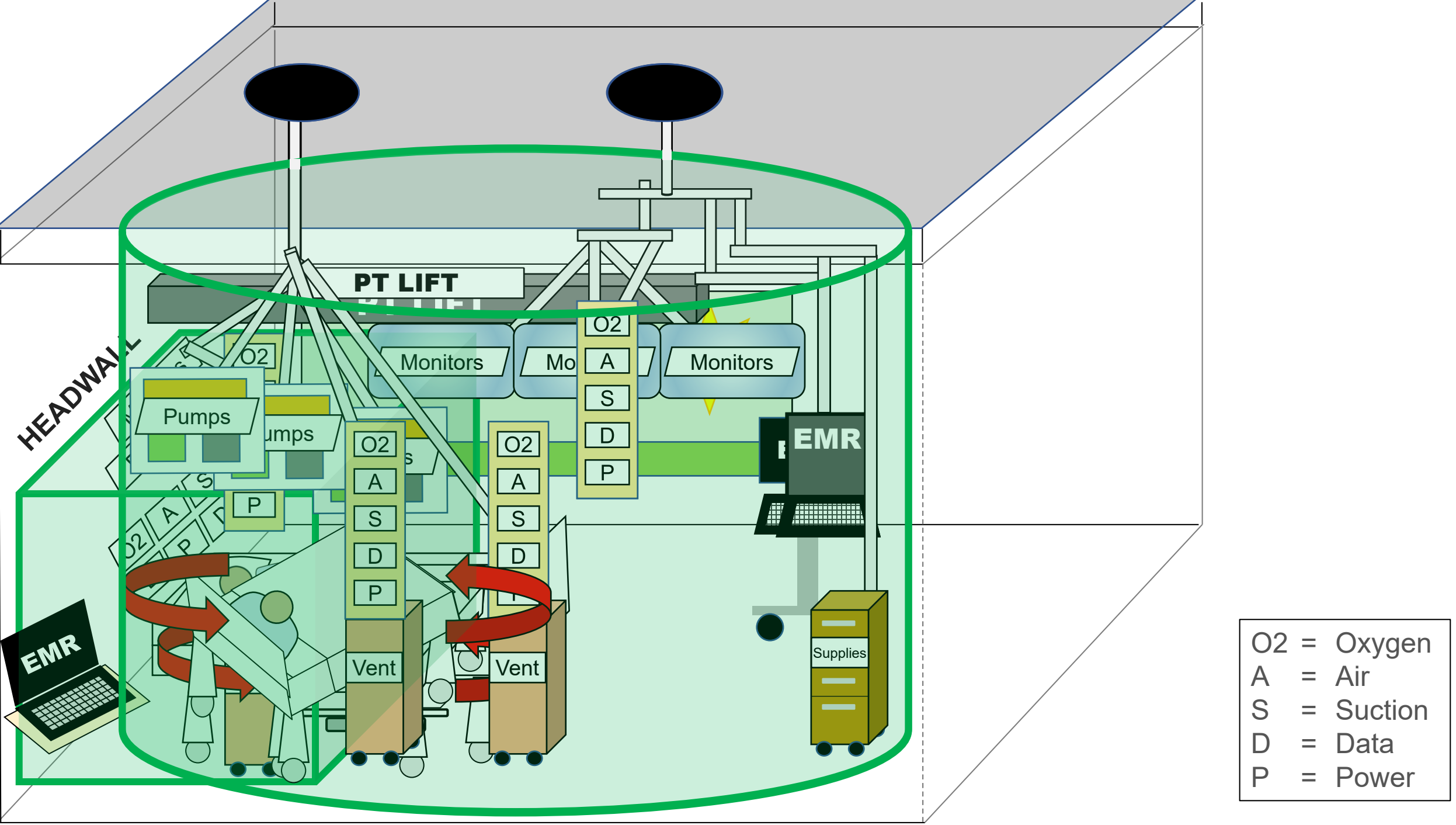
Privacy, room zones and utilities

- Privacy
  - Curtains
  - Glass doors + curtains or integrated blinds or integrated e-glass
  - Make sure the patient’s head is always visualized from the corridor regardless of privacy option or room design
- Zones of care
  - Minimal zones
  - Physical & virtual zones


Window
Vent
Monitor
Headwall
Vent
Monitor
Pumps
Supplies
Pumps
Supplies
Nurse w area
Chair
3A
3A
Chair
ICU Bed
ICU Bed
Sink
1
2
2
3B
Webcam
Wi-Fi
Family
Curtains
Curtains
Nurse Server
Sliding Doors
4
Workstation
Staging Area
1) Patient Zone
2) Caregiver Zone
3A) Family Zone (bedside)
3B) Family Zone (long-term)
4) Entryway Zone

Utilities are room's CORE: Positioning options

- Utilities
  - O2, air, suction, power, data, displays, device integrators, pt lifts
- Stationary
  - Headwall
  - Column
- Mobile
  - Mobile articulating arms (Booms)
  - Many configurations
- Hybrid (stationary and mobile)

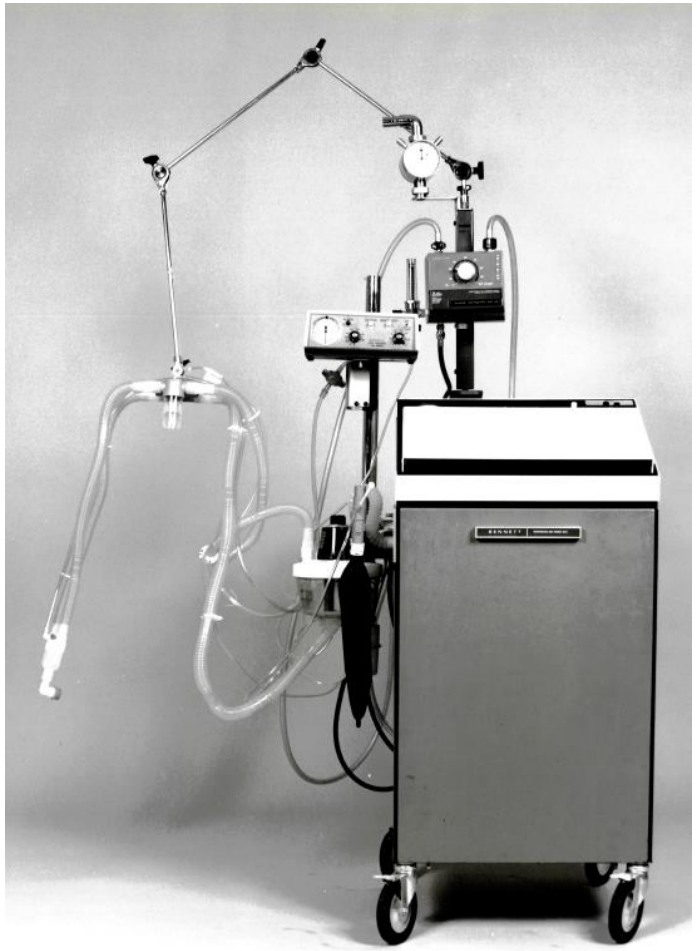

PT LIFT
HEADWALL
O2
Monitors
Mo
Monitors
O2
A
S
D
P
Pumps
umps
O2
A
S
D
P
O2
A
S
D
P
EMR
EMR
Vent
Vent
Supplies
O2 = Oxygen
A = Air
S = Suction
D = Data
P = Power

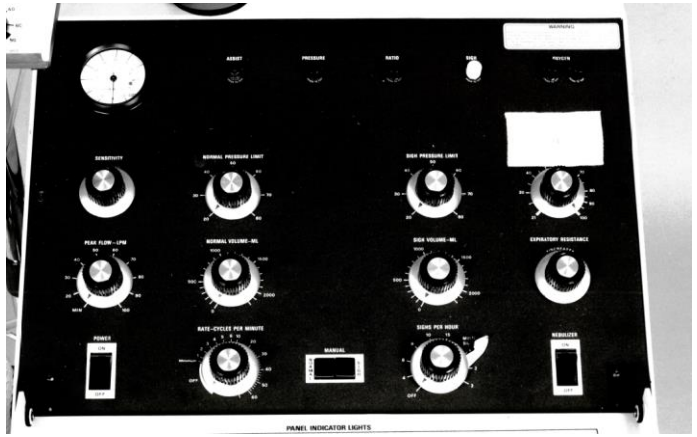
Informatics (re)evolution

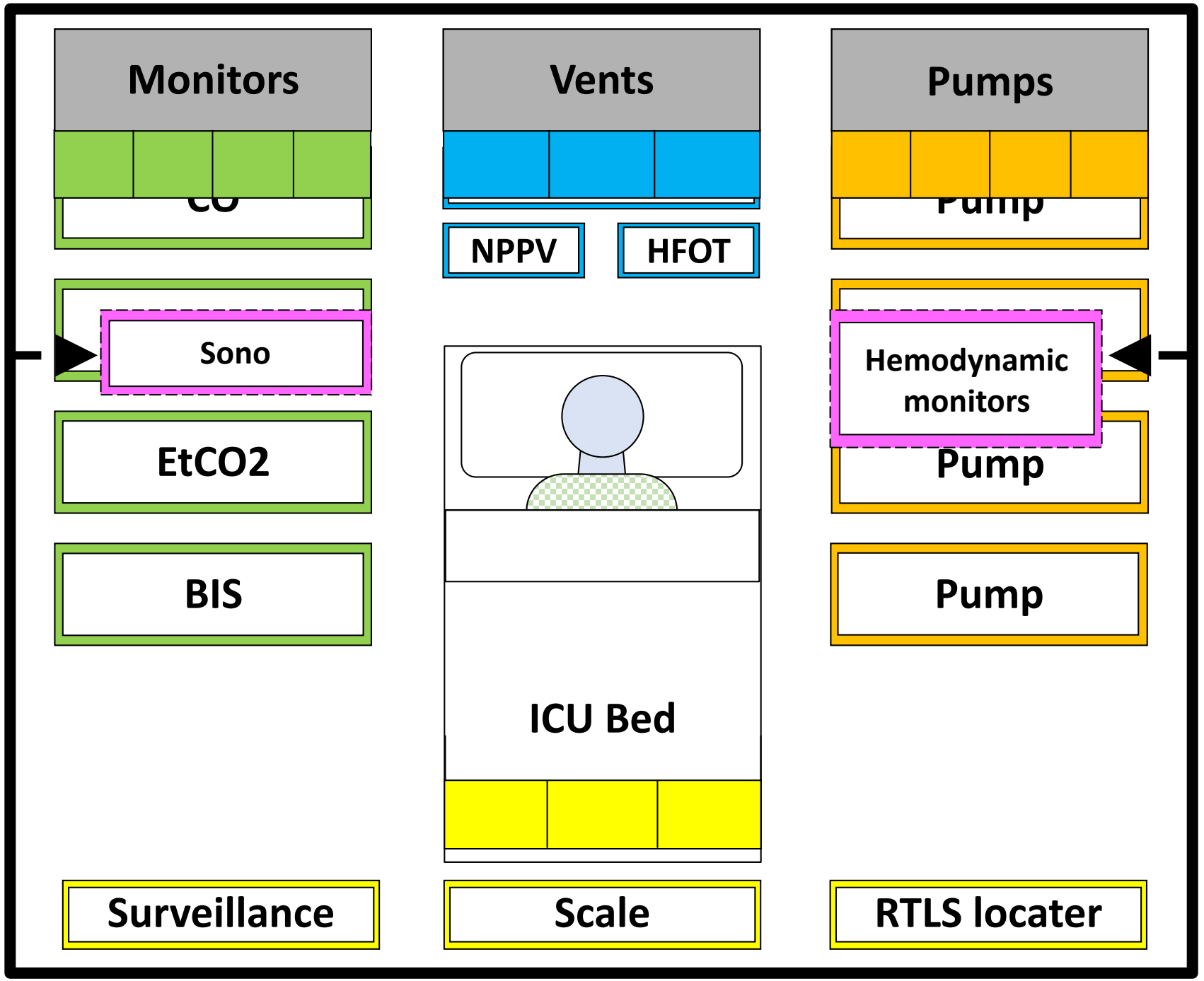
- Simple devices transition to healthcare informatics platforms
- Standalone to incorporated modules
- No association with pt to association with pt
- Paper to EHR

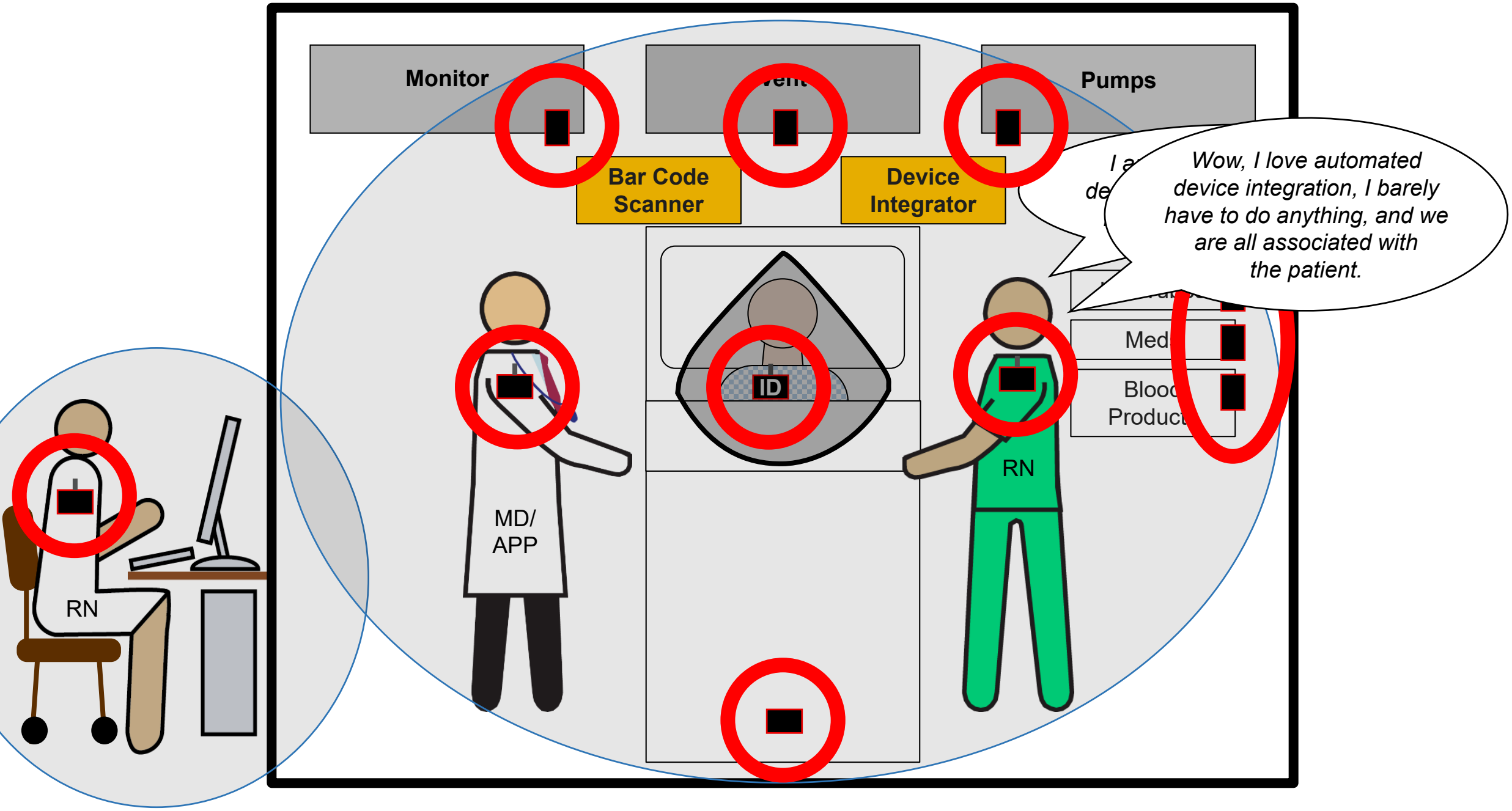
Device transformation

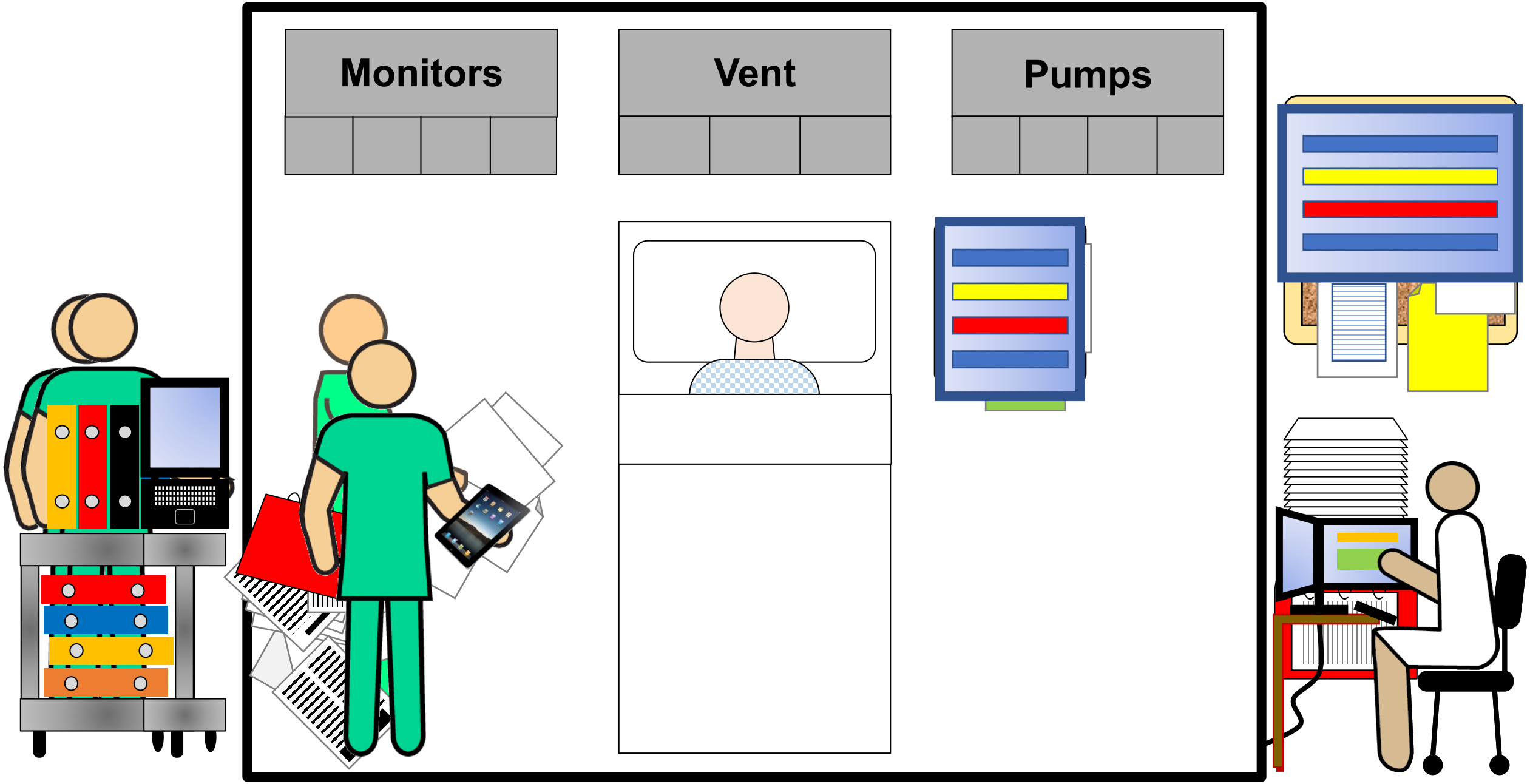
PB MA1 (1980s) to 980 (2010s)






Monitors
Vents
Pumps
NPPV
HFOT
Sono
Hemodynamic monitors
EtCO2
Pump
BIS
Pump
ICU Bed
Surveillance
Scale
RTLS locater

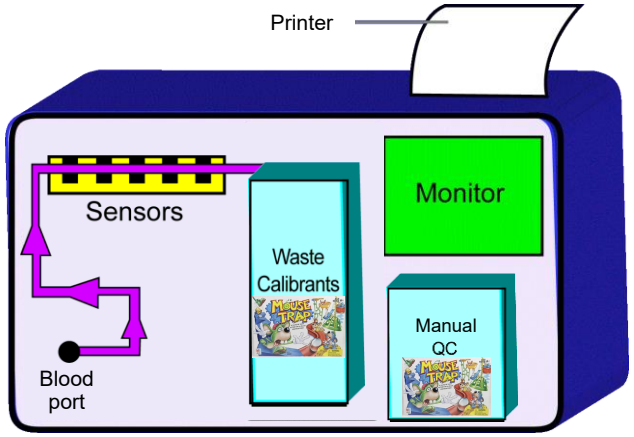

Monitor
Pumps
Bar Code Scanner
Device Integrator
Wow, I love automated device integration, I barely have to do anything, and we are all associated with the patient.
ID
MD/ APP
RN
RN


Monitors
Vent
Pumps

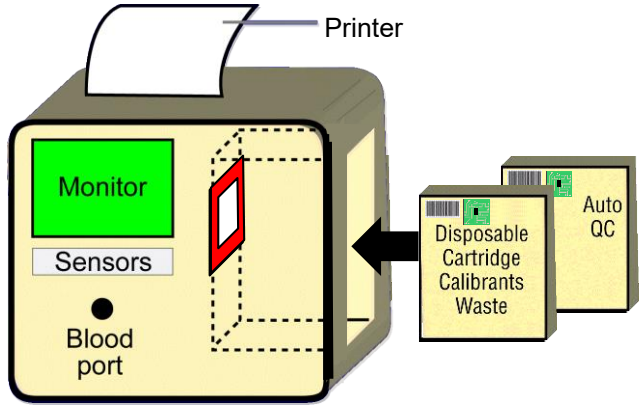
POCT device evolution

- Large & complex to smaller & simpler
- Location shifts from Lab to ICU
- Specialty Lab Techs to bedside staff
- However, great technologies come and go
- But new stuff is coming to an ICU near you

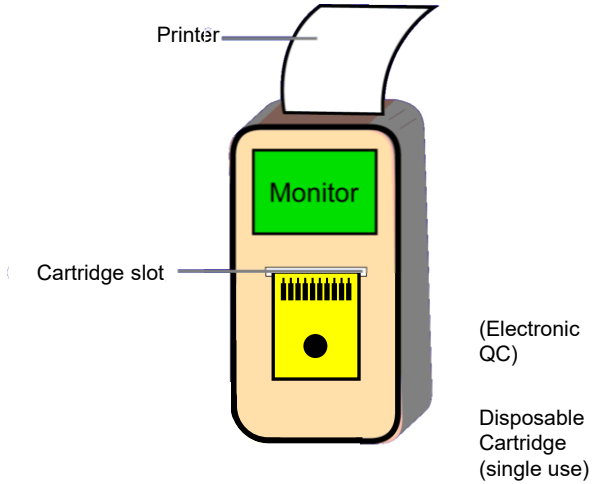
POCT Device Design Evolution



Benchtop Analyzer
(big, heavy) Manual QC



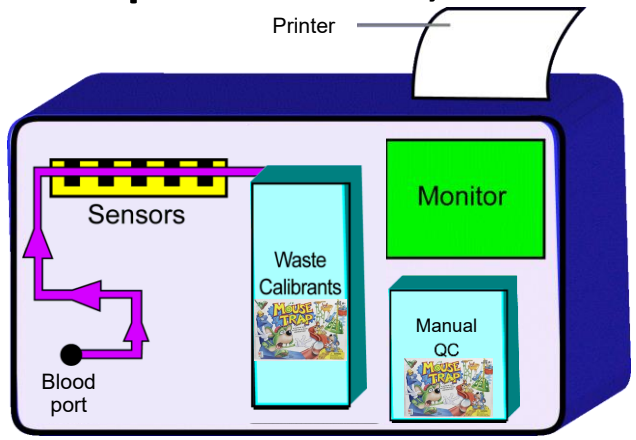
Portable Analyzer
(Multi-use cartridge)



Handheld Analyzer
(Single-use cartridge)

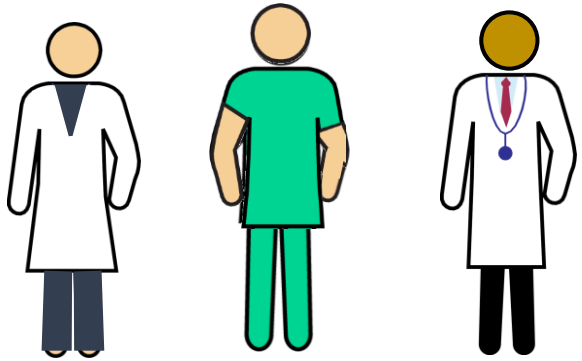
POCT Device Evolution Drives Location & Staffing

Hospital STAT Lab, ICU STAT Lab

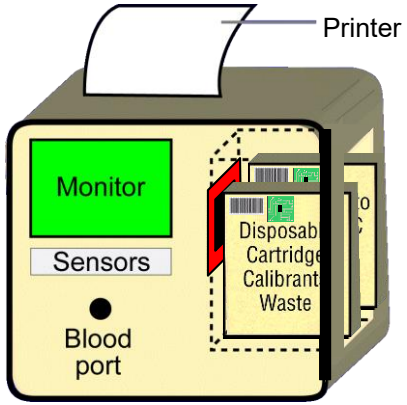


Benchtop Analyzer
(big, heavy) Manual QC

Lab Techs **RTs** **House Staff**



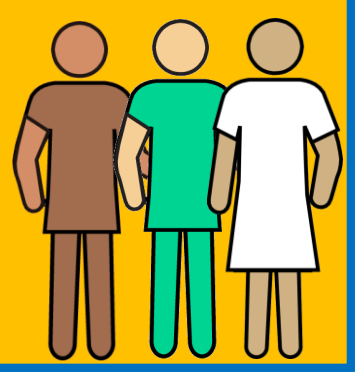
Hospital STAT Lab, ICU STAT Lab



Portable Analyzer
(Multi-use cartridge)

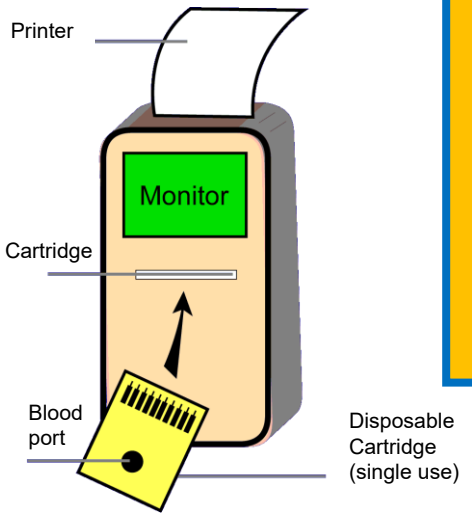
Lab Techs **RTs** **House Staff**

APPs **RNs**



ICU Bedside, Central Space

RNs

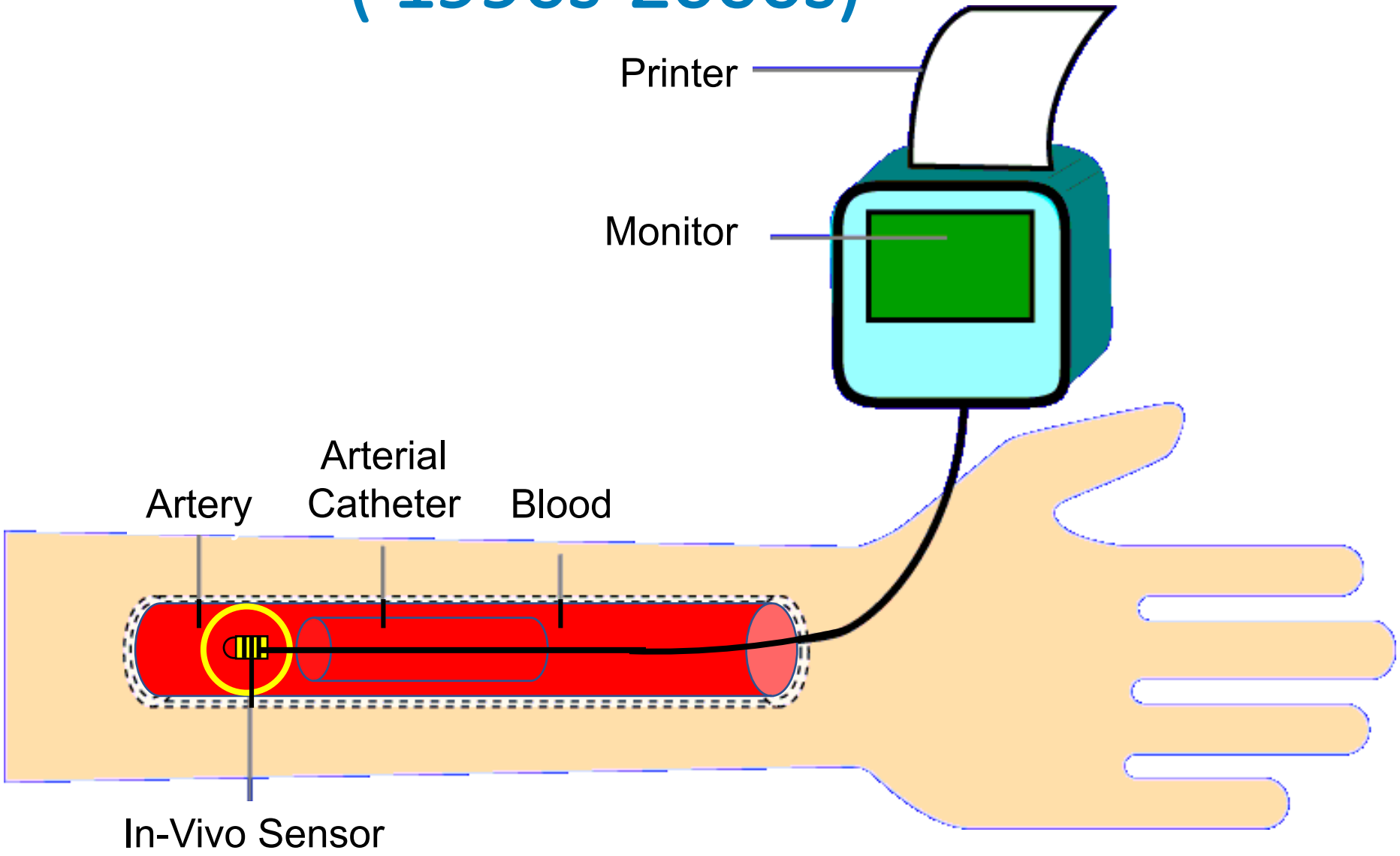


Handheld Analyzer
(Single-use cartridge)

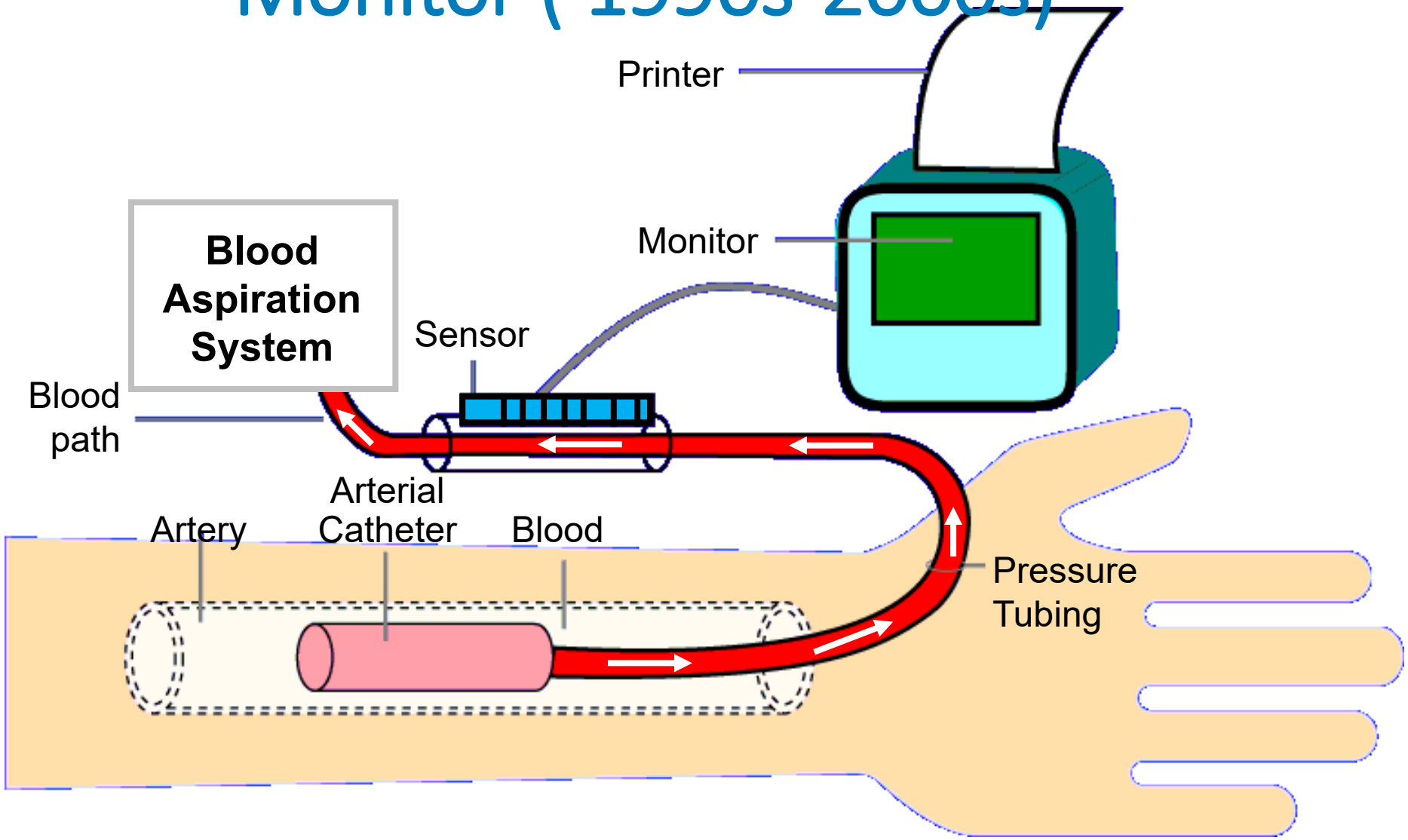
Technology drives POCT evolution

- ICU & Hospital Lab visualize new opportunities
  - New POCT technologies shift testing to ICU & bedside
- CAP (College Am Pathology) & CLIA (Clin Lab Improvement Amendment) regulations
  - Coordinate compliance
- POCT certification for ICU teams
  - Maintain certification
- POCT marketing / education needs to understand ICU staffing
  - Staff types
  - Staff by shift

POCT Device Evolution: In-Vivo Monitor (1990s-2000s)



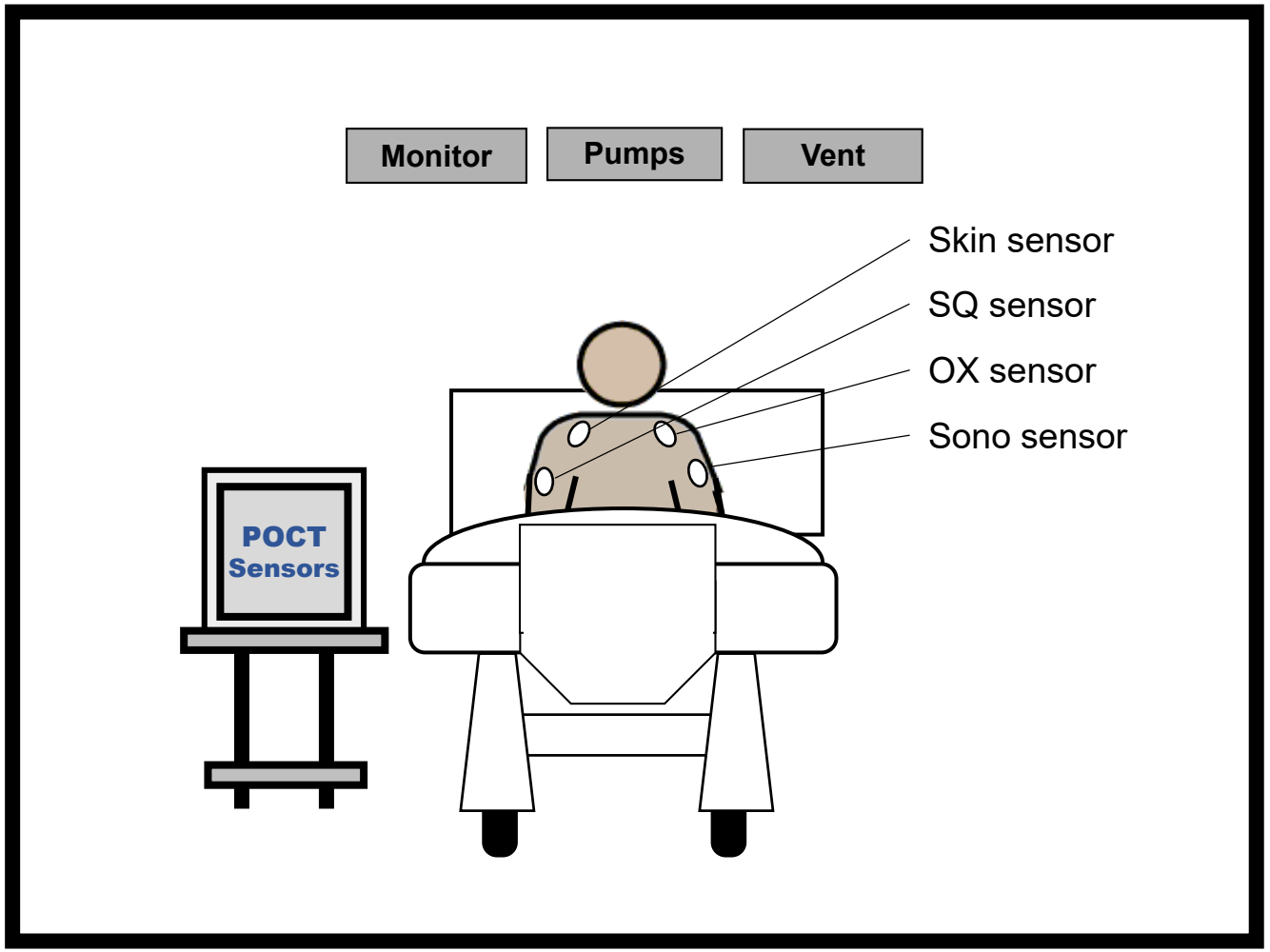
POCT Device Evolution: Ex-Vivo Monitor (1990s-2000s)



POCT evolution: In and Ex Vivo

- What happened? Gone from marketplace
  - Sensors very expensive
  - Too much data & no data manager
- Future (hopeful):
  - Sensors will offer more analytes
  - Sensors less costly
  - Improved data management
  - Device integration

ICU POCT steps into the future



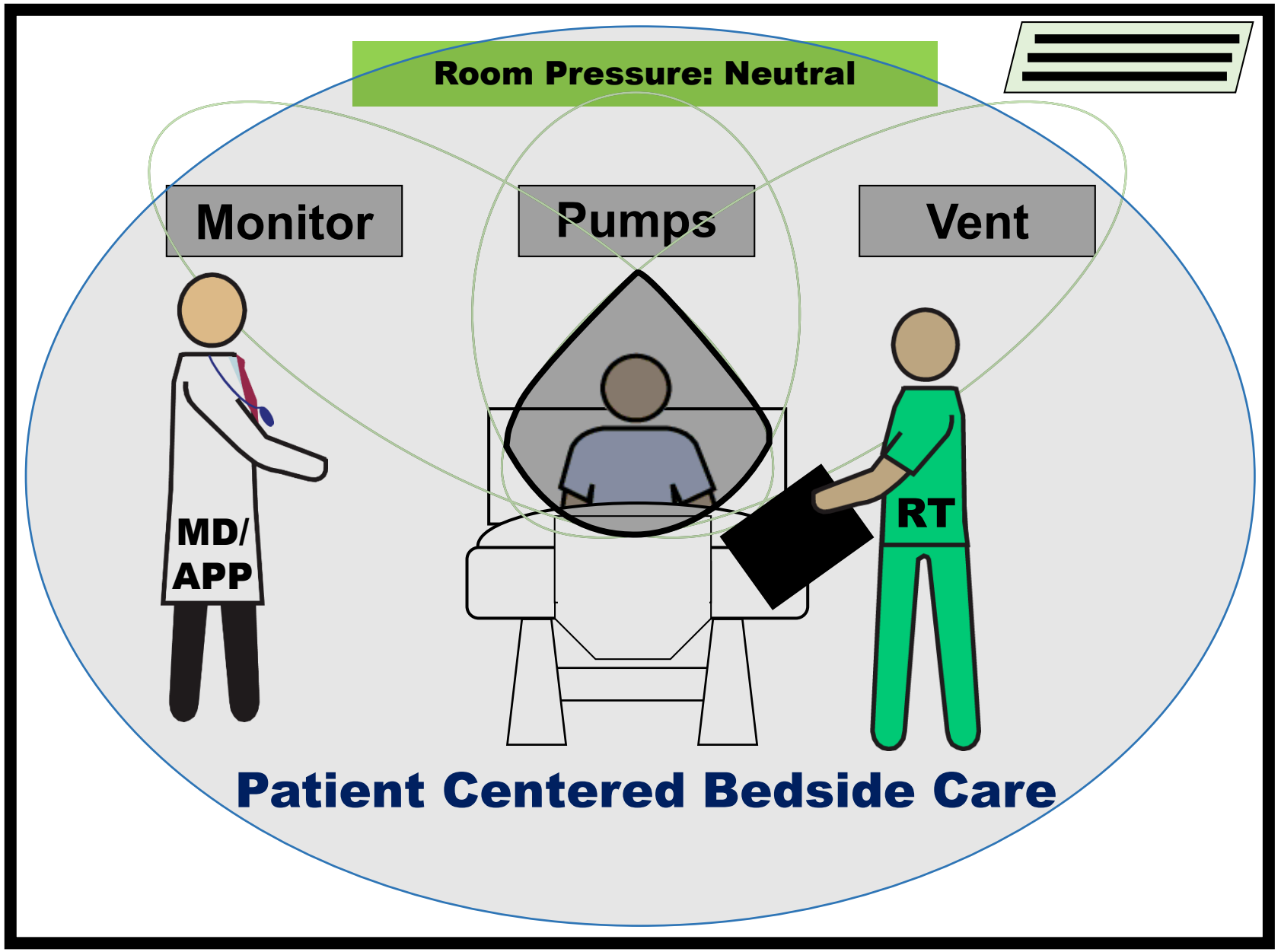
Evolution of care models

- New staff joins the ICU team
- Patient centered bedside care
- Tele-critical Care
- Bedside plus Tele-Critical Care
- And then COVID 19 came along!

Transition: ICU staffing

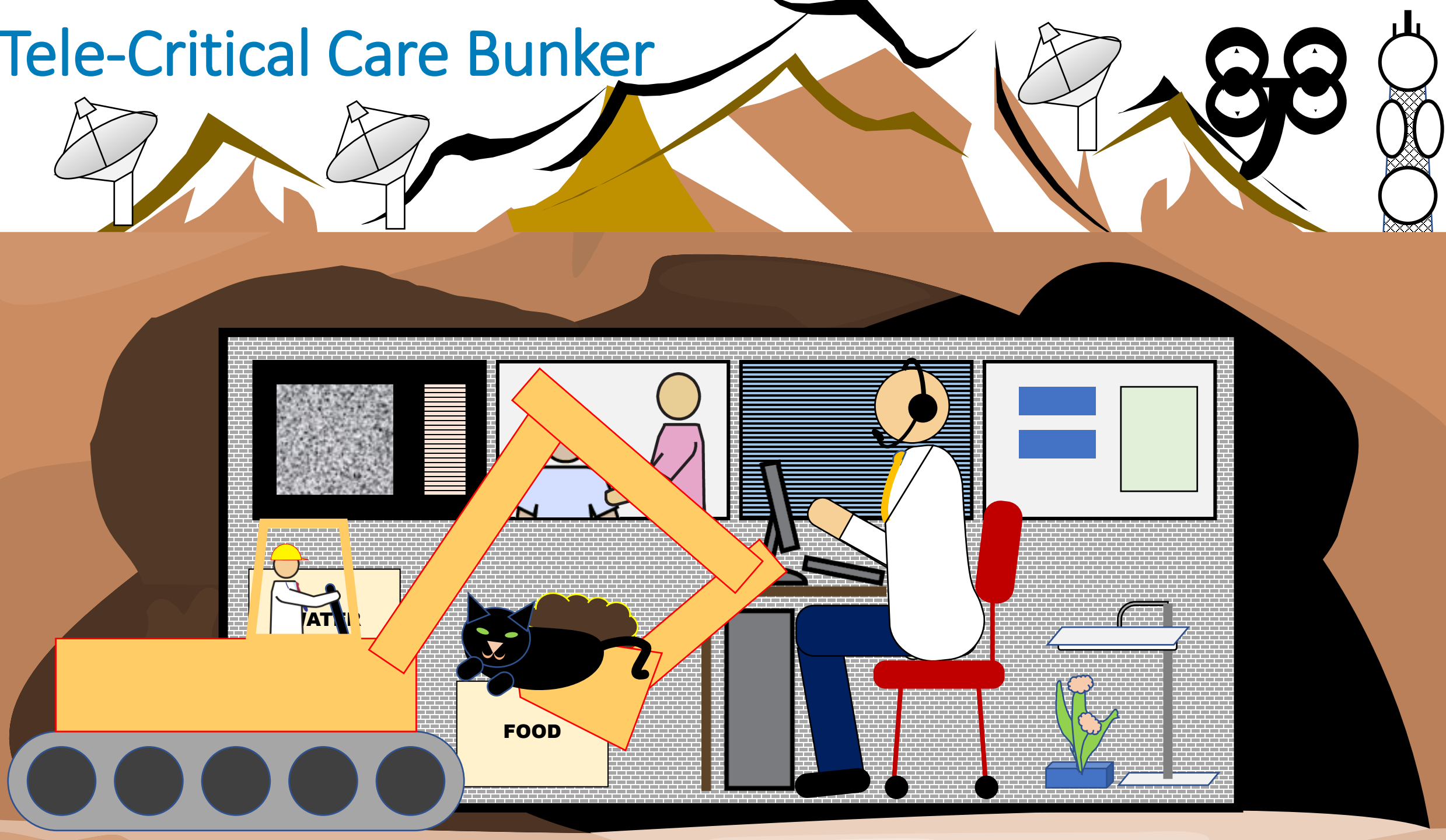
- 1960s-2000s
  - RNs RTs MDs House-staff Med students Lab techs

Evolving Model of care: Bedside Care

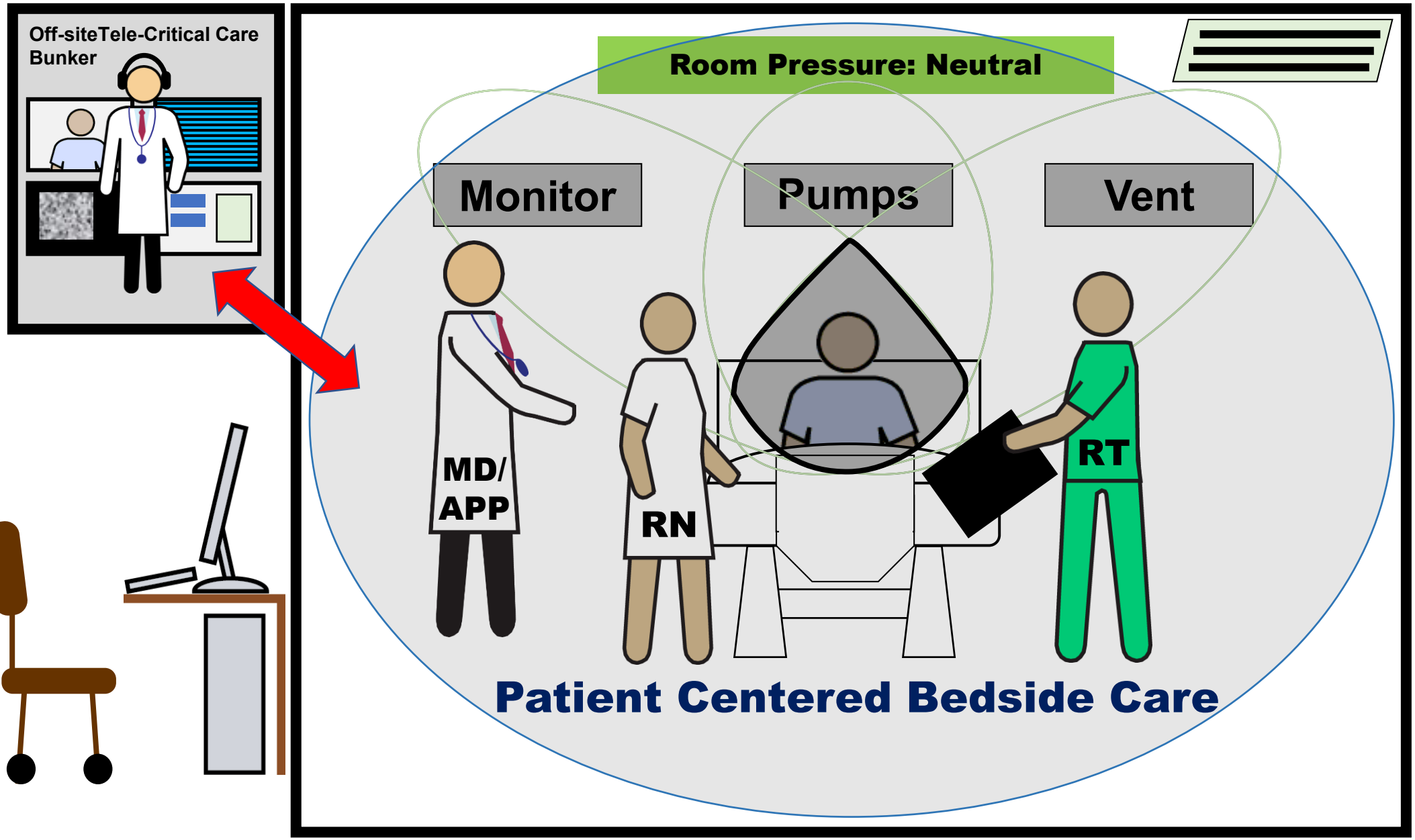


Air duct

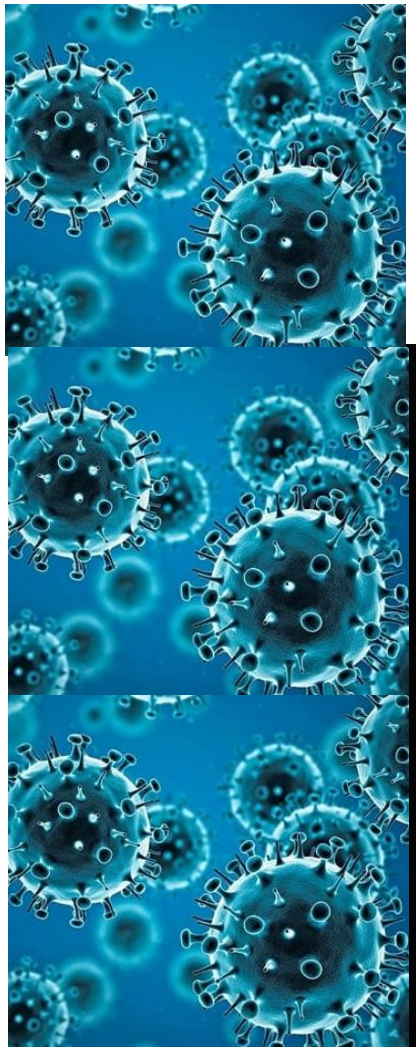
Tele-Critical Care Bunker



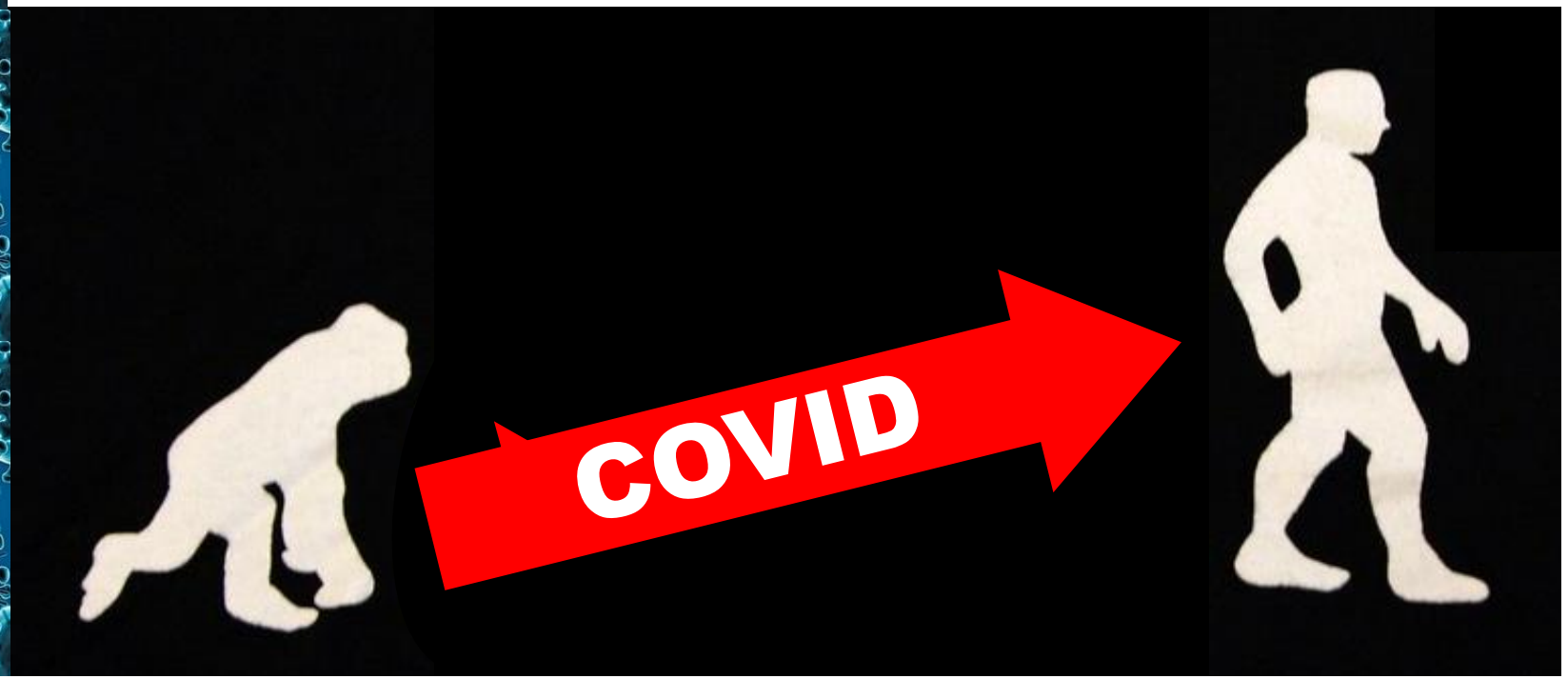
Evolving model of care: From the bedside to the bunker



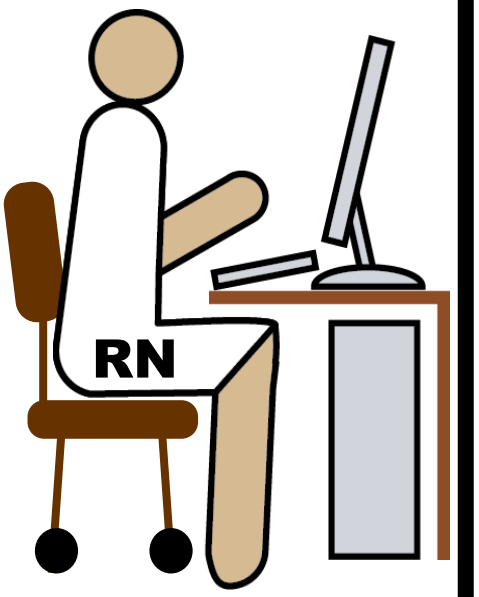
COVID 19 speeds up ICU design evolution



Here (2022) → **There (2030)**

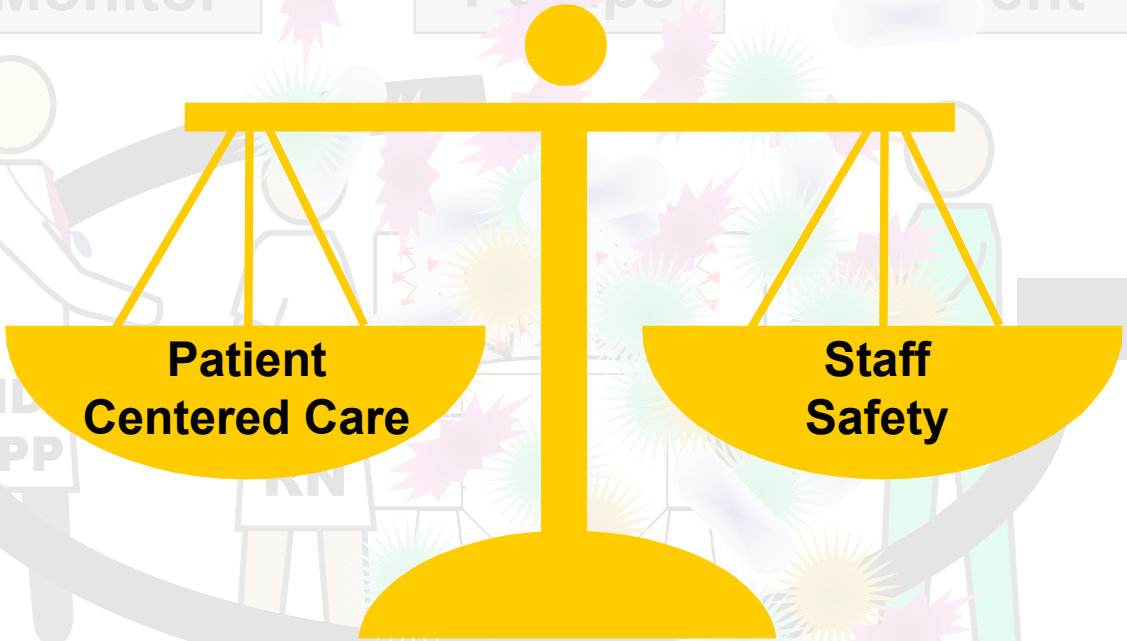


Evolving model of care: Rethinking the model

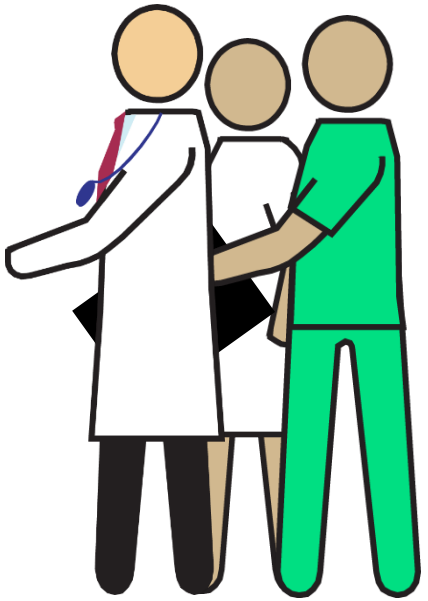


Room Pressure: Negative

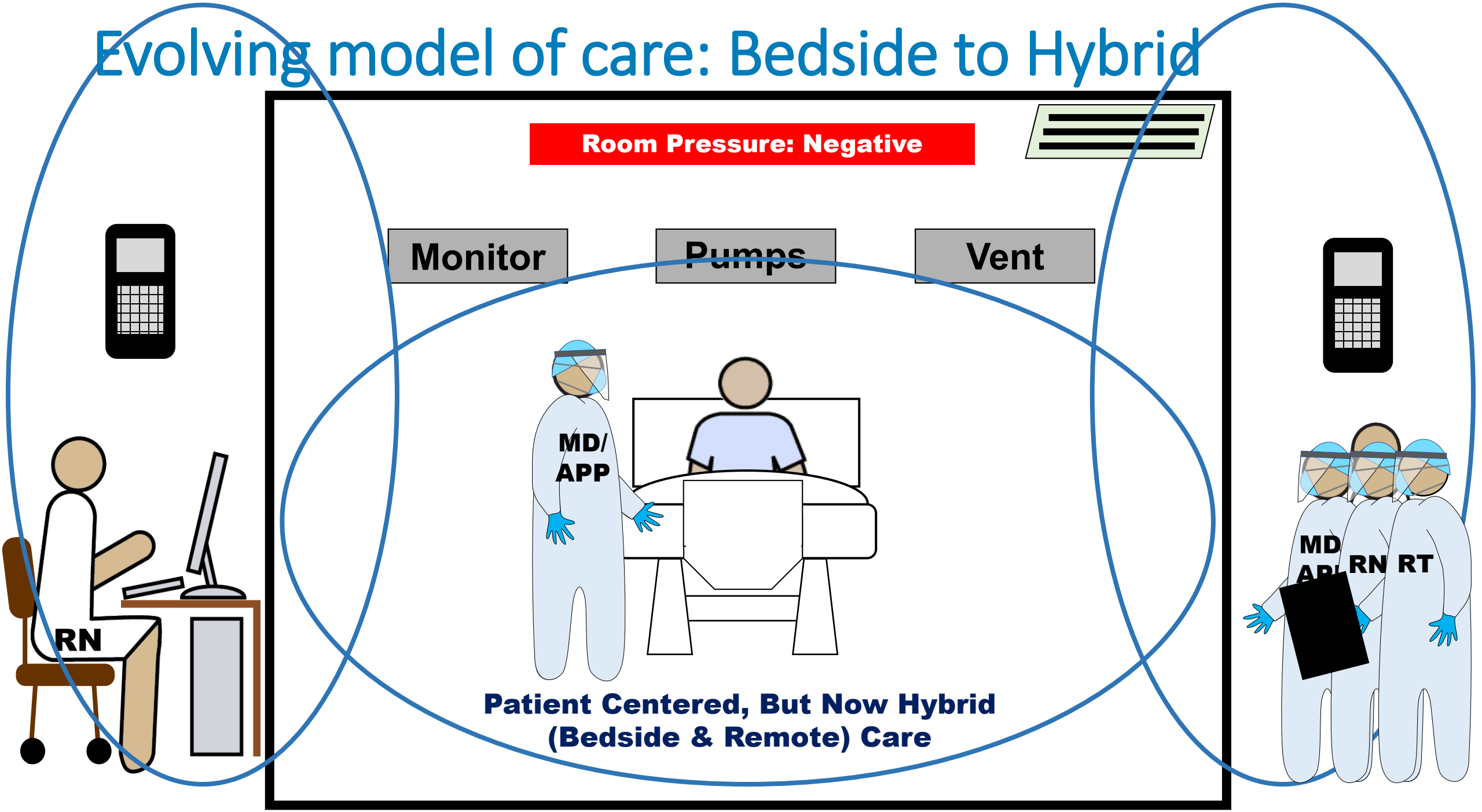
Need to Rethink Care Model



Hybrid (Bedside & Remote) Care

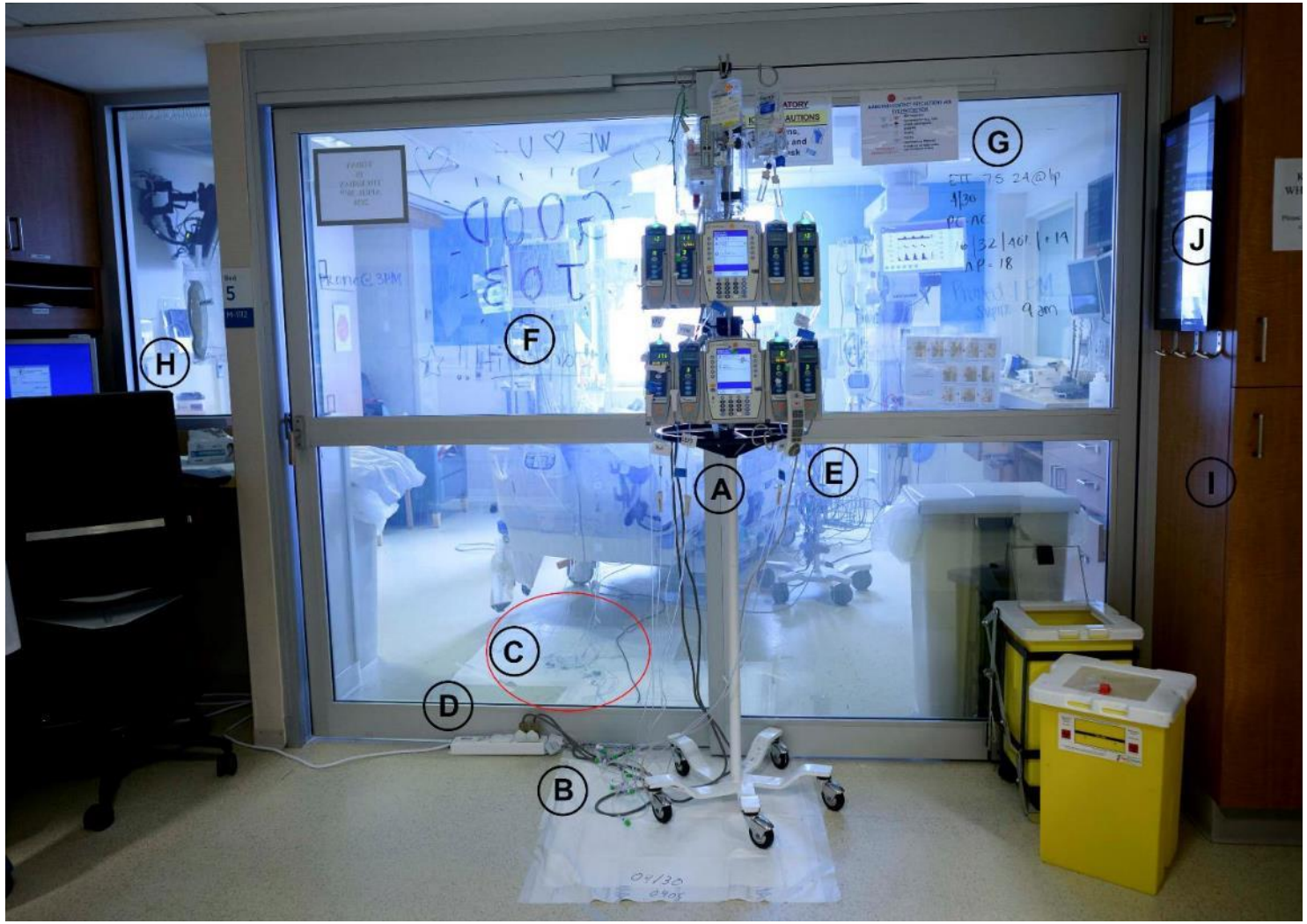


Evolving model of care: Bedside to Hybrid



MSK Main ICU- Pre COVID

MSK COVID-19 Main ICU / Hybrid Care

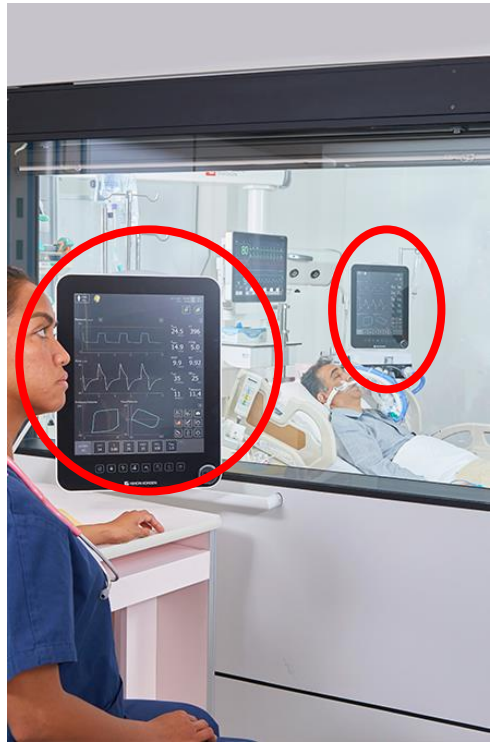


Remote Monitoring vs Remote Management

Remote monitoring allows for view only of device settings and data.

Remote management permits the changing of device settings through bidirectional communication.

Remote Ventilator Management

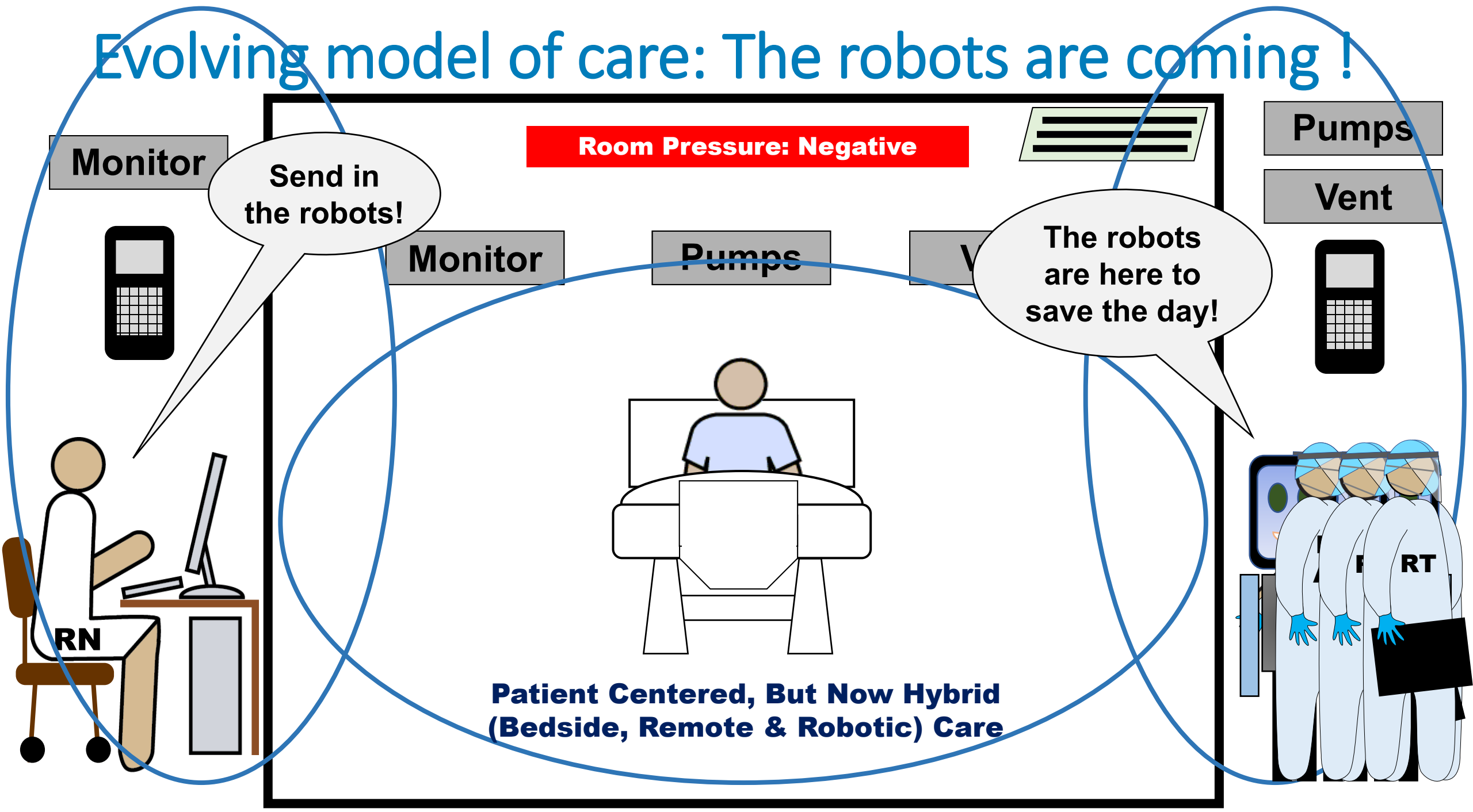


- Existing ventilator pre COVID-19 with FDA clearance for remote ventilator management
- Remote control via fully functional secondary user interface
- Negates patient safety issues of moving entire device outside of room

- March 2020, ventilator granted EUA for software upgrade providing informatics based remote control
- Software enabled remote control via computer attached to hospital's local network
- Limitations: use only COVID-19 patients during public health emergency

https://orange-med.com/applications/

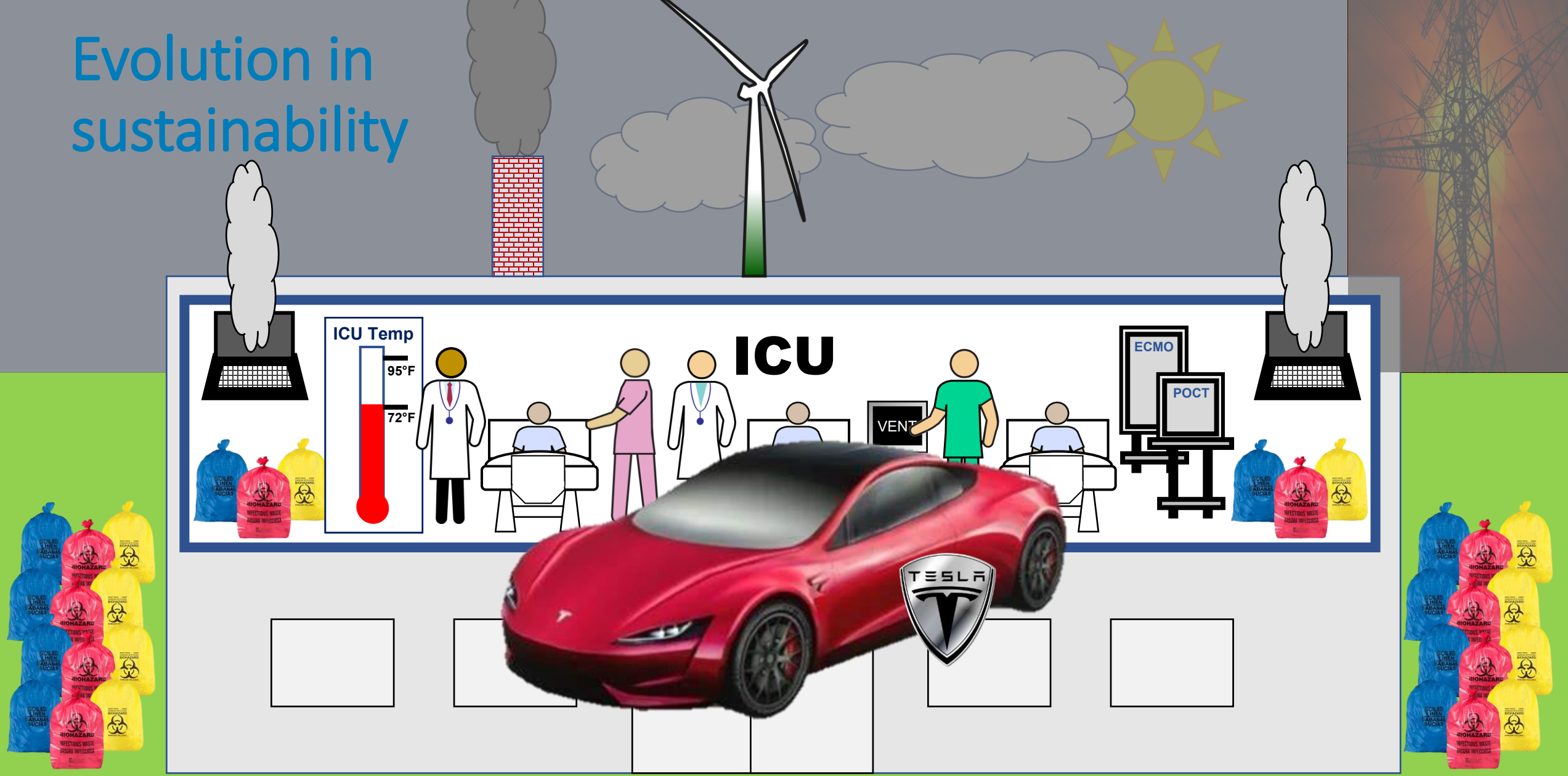
Evolving model of care: The robots are coming !



Sustainability comes to an ICU near you

- 1960s to 2020s
  - Never thought about the ICU from an environmental perspective
- 2020s onward
  - Sustainability – **GREENING** comes to ICU within context of hospital

Evolution in sustainability



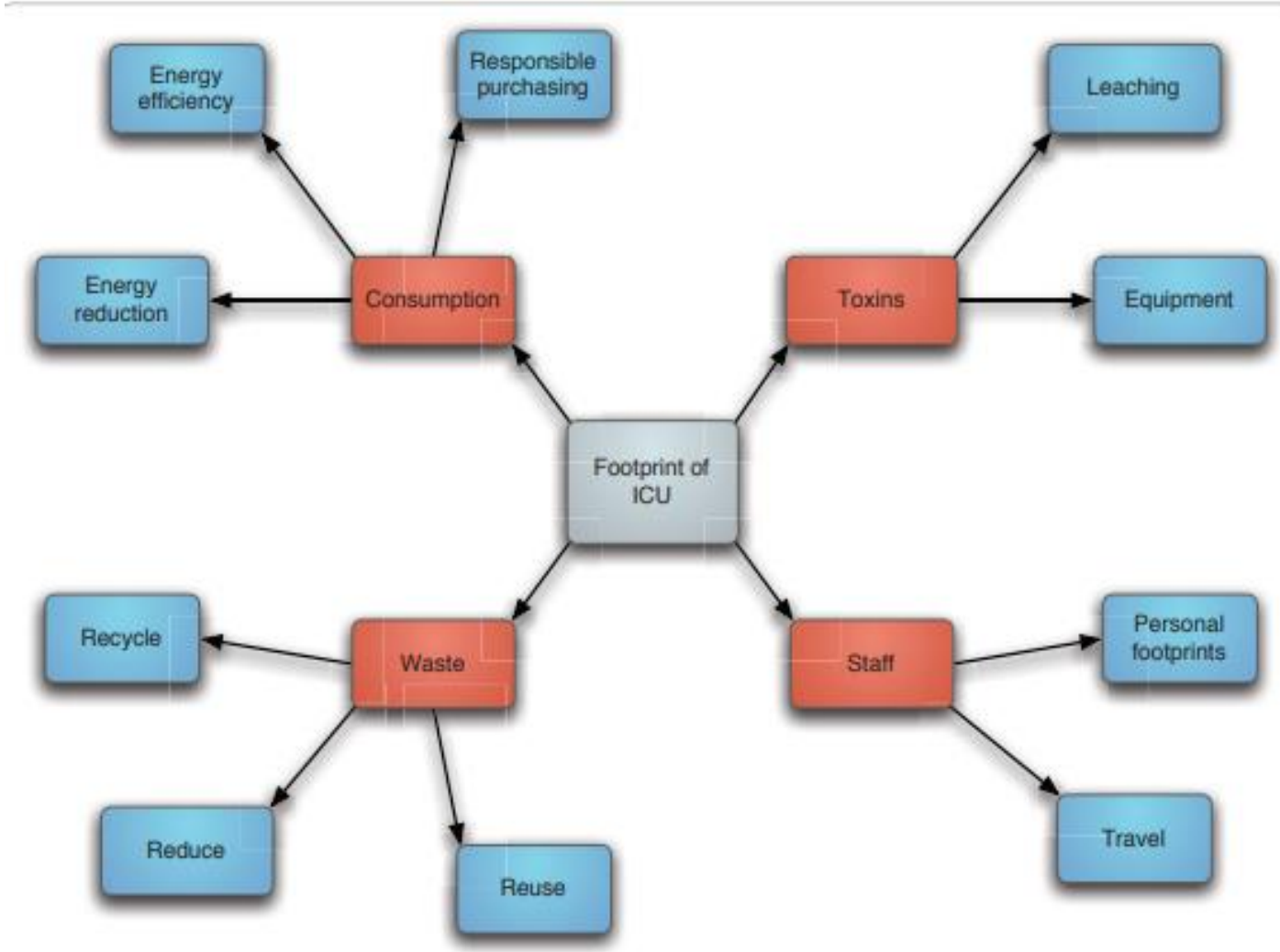
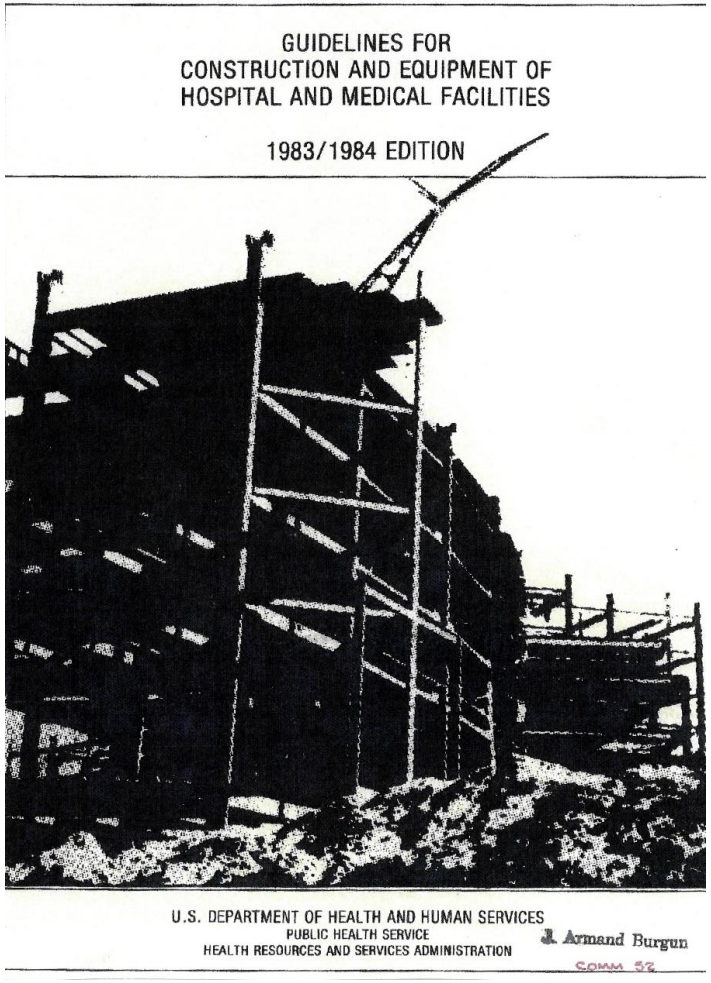
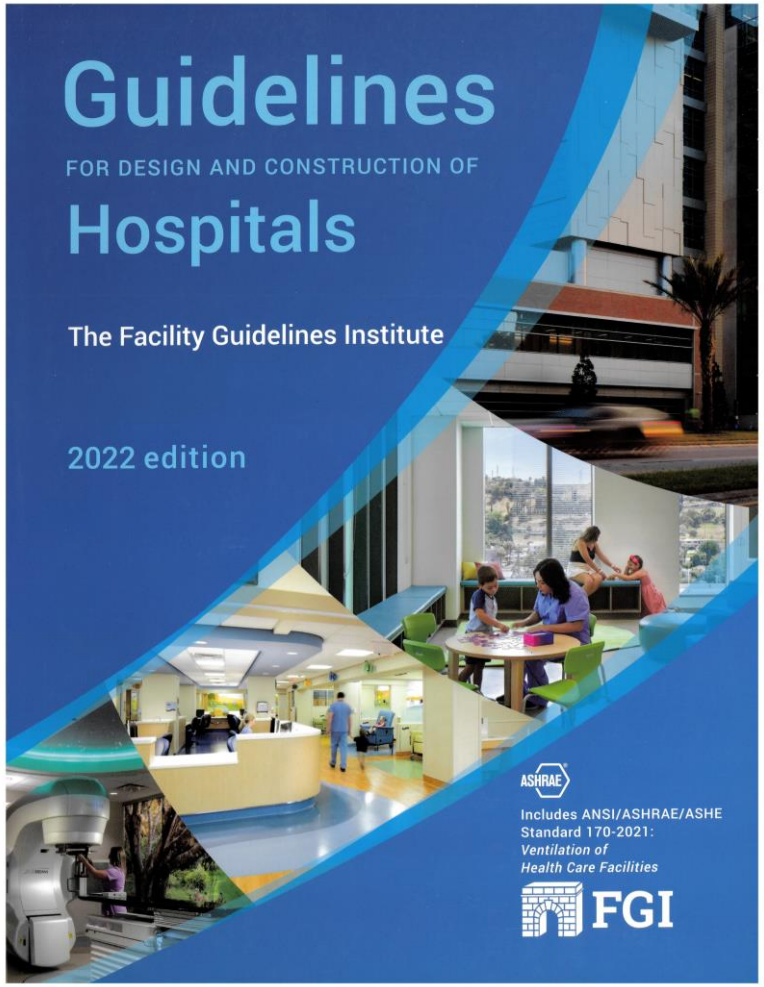


Figure 1. Reducing the environmental impact of an intensive care unit: four focus areas.

US-DHHS 1983-1984 vs FGI 2022





ICU design evolution: FGI 1984 vs 2022 (1)

MID 1980S
Small ICUs located anywhere
Open space for patient
Central work/staffing spaces
No corridors
Stationary support (headwalls or columns)

ICU design evolution: FGI 1984 vs 2022 (2)

MID 1980S
Minimal concerns for ICU environment
Paper health record
Standalone medical devices
No informatics
Care monitored and rendered locally
No thought for the future

Evolving an ICU in place

Case Study

THE CENTER FOR HEALTH DESIGN®

Health Environments Research
& Design Journal
1-20

DOI: 10.1177/1937586720918225
journals.sagepub.com/home/her
SAGE

Keeping a 2009 Design Award–Winning Intensive Care Unit Current: A 13-Year Case Study

Neil A. Halpern, MD, MCCM, FACP, FCCP[1,2], and Diana C. Anderson, MD, ACHA[3,4]

Enhancements in the ICU & Supporting Platforms

- ICU workflow and staffing model
- ICU corridors
- Supply rooms and infection prevention
- Conference room renovations
- Reallocation of space for new or expanded programs
- Critical Care academic office
- Enhanced patient experience
- Central staffing areas
- Patient rooms
- Middleware
- Enhancements tried or investigated but could not yet be implemented

Futureproofing: Designing for the future

Based on what we know today, we need to design the ICU to enable future modernization beyond current needs

- Excess electrical power
- Digital support
  - Large informatics infrastructure closets
  - Enabling cable replacement
  - Easily replaceable switches
- Floors with high weight-load capacity
  - Mobile Scanners
- Large spaces between floors
  - Space between floors / cement palates
    - (over the ceiling tiles)

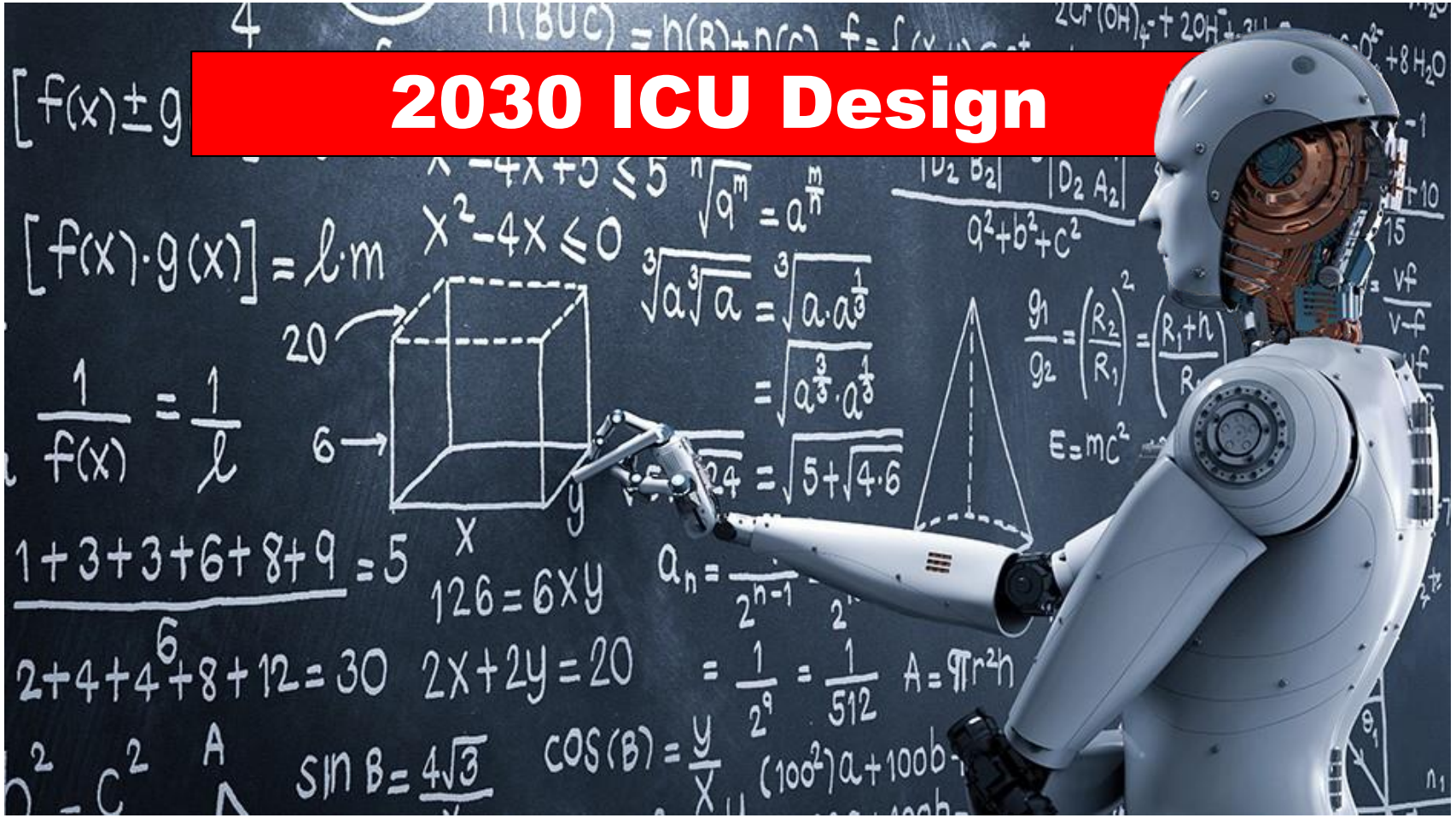
AI evolution

Evolving terminology

- Machine learning
- Artificial neural networks
- Predictive analytics
- Prediction algorithms
- Learning based AI
- Generative AI
- ChatGPT (OpenAI)

AI designs new ICU

AI Designs New ICU



Conclusions

- ICU design has evolved over 4 decades
- ICUs design & approaches to care respond to enhancements in staffing, technologies, space, needs & societal imperatives
- Designing for the future is doable, except we don’t know the future!