作業系統分析及應用科技改進藥療系統及作業

Operating System Analysis and Application Technologies for Advancing Medication Use Systems

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Objectives

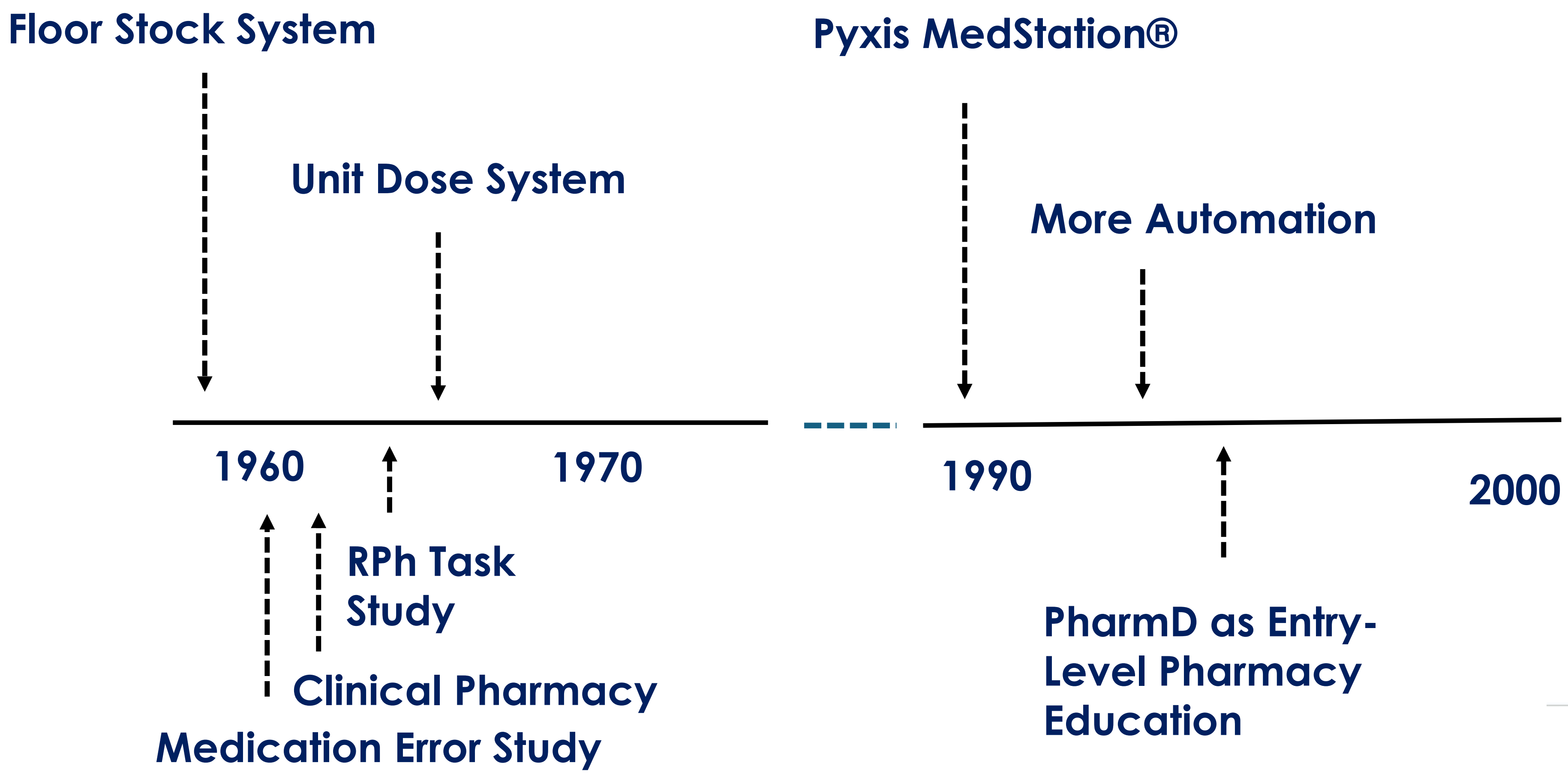
To discuss the following:

1. Traditional operational analytics tools used in improving medication use systems
   - Observation
   - Workflow analysis
   - Work measurement
   - Facility design
   - Computer simulation
2. Pharmacy 5.0, its framework, and the analytics tools and technologies, including Lean Six Sigma, robotics, artificial intelligence (AI), virtual reality (VR), augmented reality (AR), and wearables.

Medication Use System

A system that has as its purpose of selection, acquisition (from the manufacturer), control, storage, dispensing, delivery, preparation, and administration of drug products in health care institutions in response to the order of an authorized prescriber.

Evolution of Medication Use System in the US



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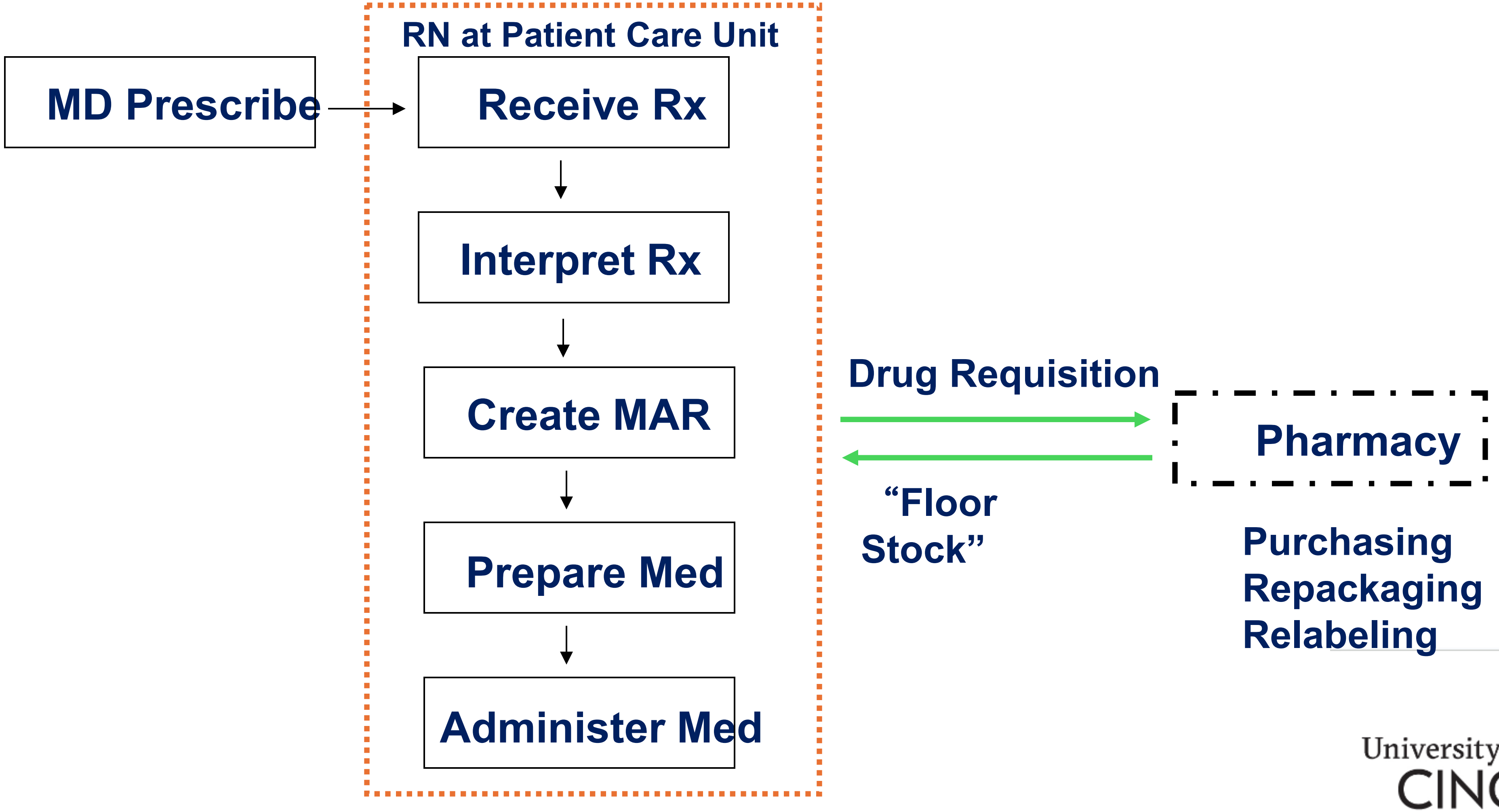
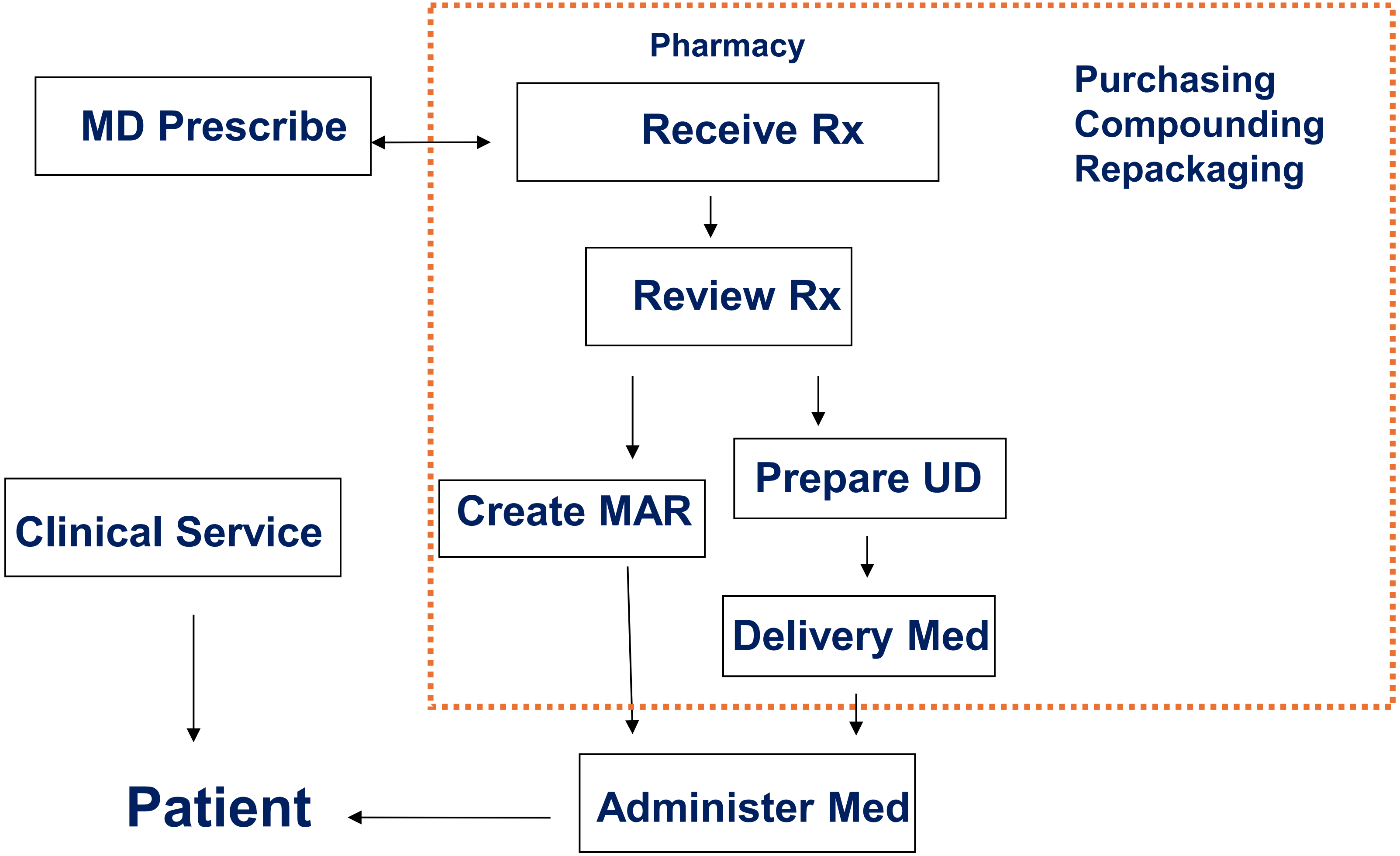
Once Upon A Time…
Institutional Medication Use System

Floor Stock System

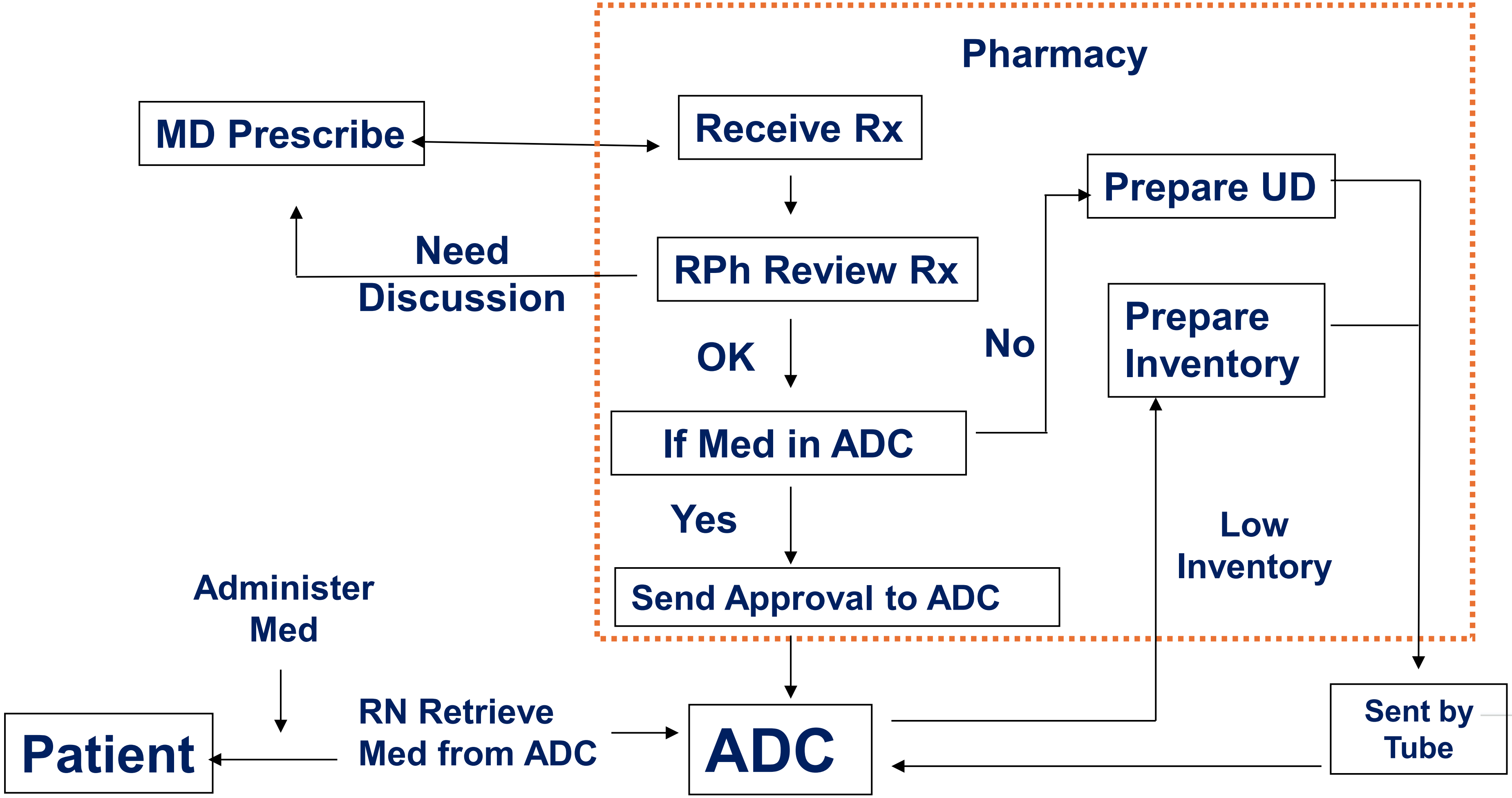


Improved - Unit Dose Drug Distribution System

Unit Dose System



NOW - Institutional Medication Use System



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Traditional Operational Analytics Tools Used in Improving Medication Use Systems

1) Observation
2) Workflow analysis
3) Work measurement
4) Facility design
5) Computer simulation

Observation - Determine Medication Errors

- Medication errors are defined when the doses patients receive differ from the prescribed orders.
  - Errors include wrong medication, incorrect dose, wrong route, wrong time, etc.
- Barker et al., assessed three methods, observation, self-report, and study of existing records, of detecting medication errors, and to determine some of the factors important in motivating nurses to report them.*
- Observation is the act of carefully watching, listening, or noticing something to gather information. It involves using your senses or instruments to collect data.

*KN, Barker, McConnell WE. “The Problems of Detecting Medication Errors in Hospitals“, American Journal of Hospital Pharmacy, Volume 19, Issue 8, 1 August 1962, Pages 360–369, https://doi.org/10.1093/ajhp/19.8.360

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Observation to Determine Medication Errors (Cont'd)

- Approach:
  - Observe medication administration without knowing the prescribed doses– record, patient, nurse, drug name, strength, route, time, etc.
  - Review prescribed order after observation
  - Smart process to avoid legal issues
  - Classify error types
- Led to the creation of a new unit dose medication use system.

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Workflow Analysis

- **To identify all steps involved in all process**
- **Standard symbols**

Symbol	Description
○	Operation
⇨	Transportation
□	Inspection
D	Delay
▽	Storage

Workflow Analysis (cont'd)

- To identify all steps involved in all process
- Two systems
  - Informational analysis
  - Operational analysis
- Steps
  - Determine the functions/activities
  - Review the document (i.e., pharmacy policies and procedures)
  - Interview
  - Chart the process
  - Validate process

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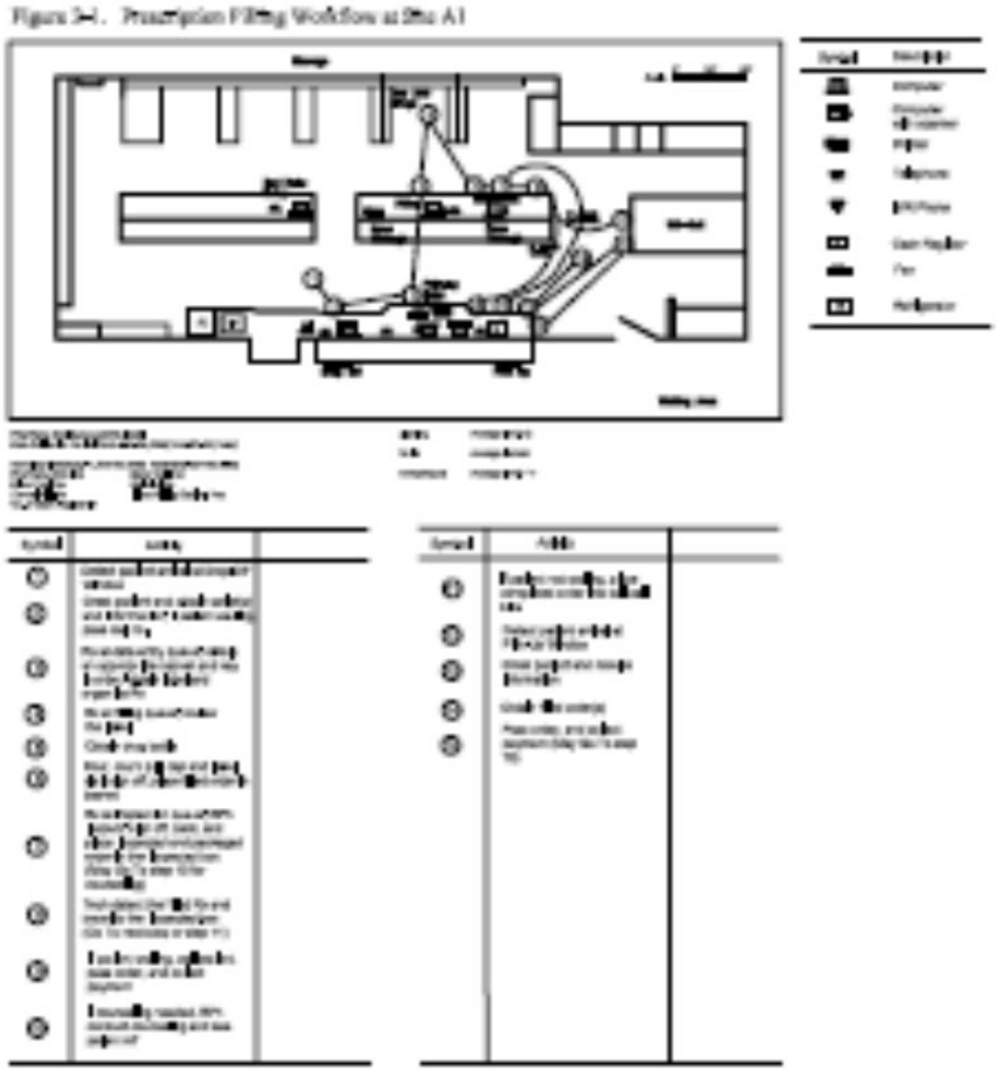
Example of Workflow Analysis Results

Travel in Feet	Symbol	Description
3	⇨	Go to printer
	○	Read, and tear off label
6	⇨	Go to storage
	○	Obtain drug bottle
6	⇨	Go to Filling Station
	○	Count/pour drug
	○	Attach label, and place filled Rx on counter
	D	Wait for R.Ph. check

Summary

		Frequency
Operation	○	4
Transportation	⇨	3
Delay	D	1



Benefits of Workflow Analysis

- Standardize the process
- Visualize the process
  - Better understand the overall process
  - Detect the unnecessary steps (reduce unnecessary motions)

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Work Measurement

- To determine the effectiveness and efficiency of medication use system
- Work sampling
  - Random
  - Fixed-interval
- Stopwatch

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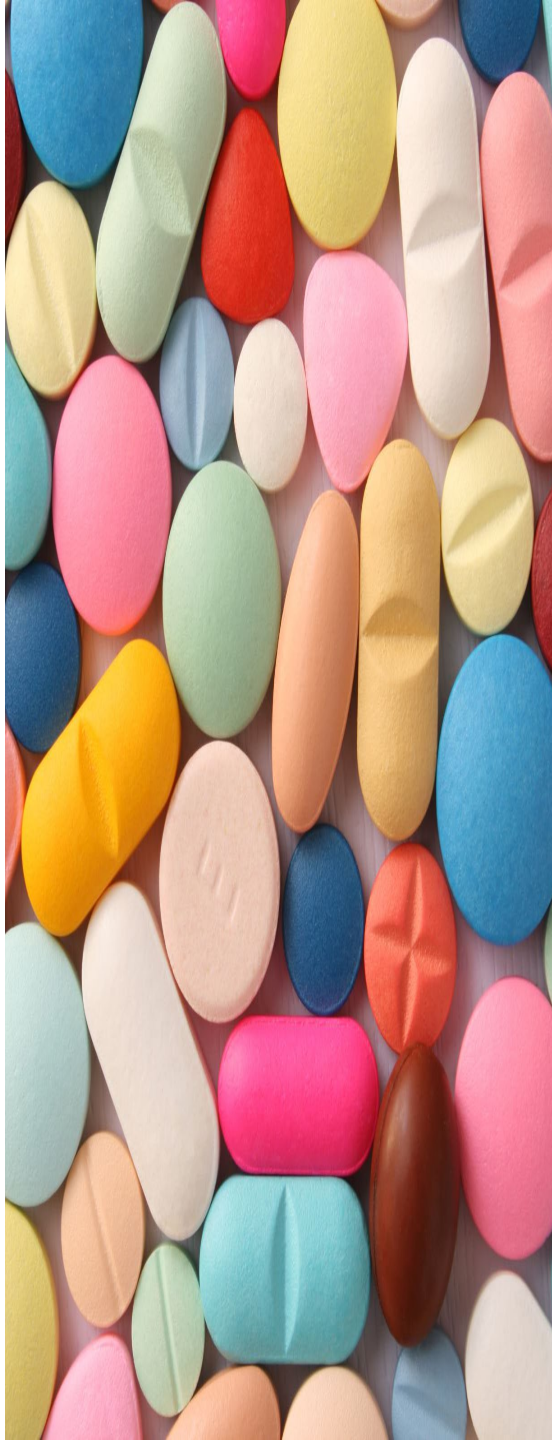
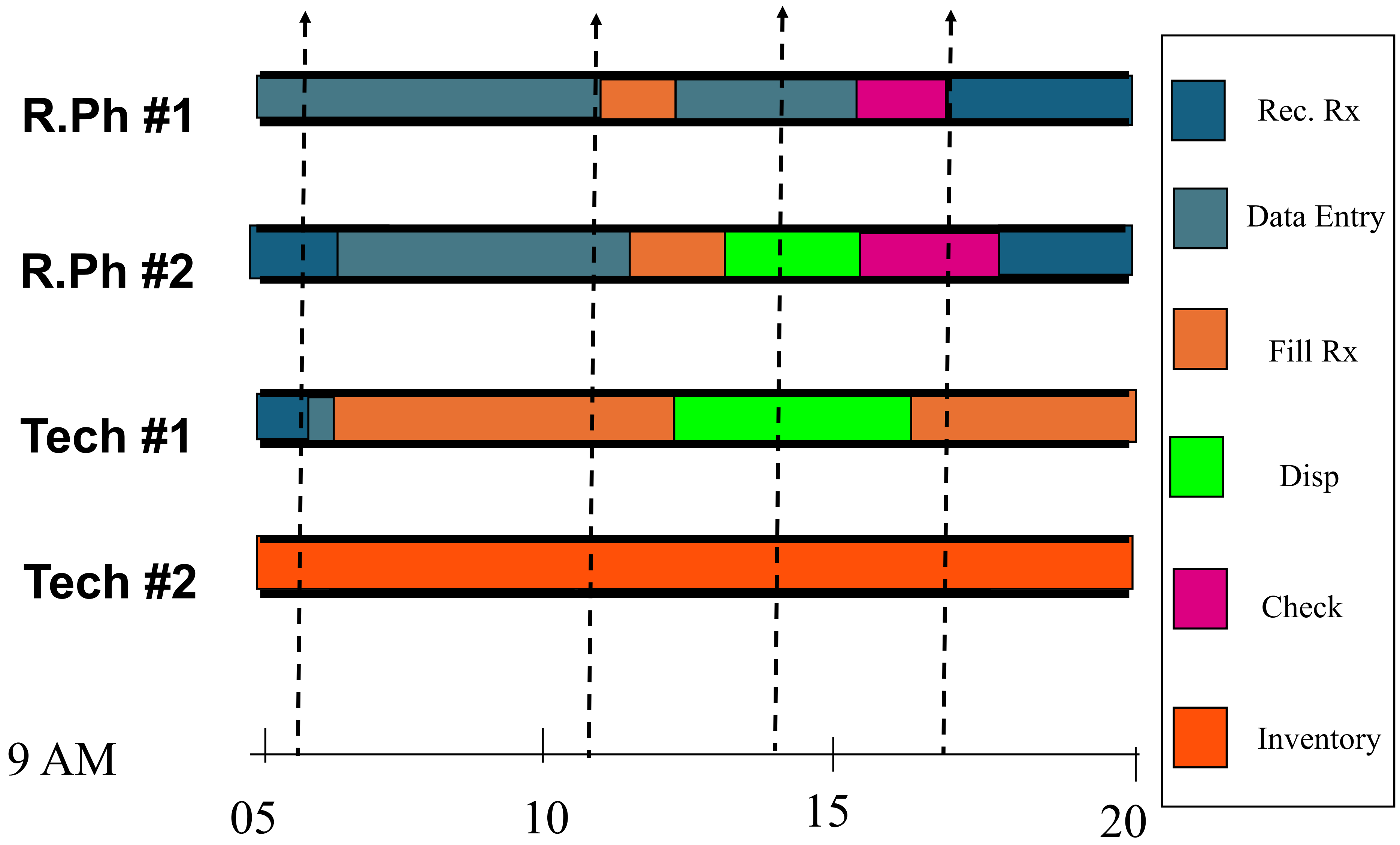
Work Sampling - Pharmacist Task Analysis

- Kenneth N. Barker published his pharmacist task analysis in 1975.
- Applied work sampling to detail the activities and responsibilities of pharmacists, providing a systematic framework for understanding the scope of pharmacy practice.
- A pivotal study that helped shape the development of modern pharmacy roles, particularly in clinical settings.
- Resulted in the expanding duties of pharmacists beyond dispensing, including drug therapy management, patient counseling, and collaboration with other healthcare professionals, aligning with the evolution of clinical pharmacy practice.
- Laid the ground work for using of pharmacy technicians



Concept of Work Sampling



Work Sampling

- To quantify overall of the system performance (effectiveness)
- Steps
  - Define the study objectives
  - Define the categories
    - e.g., Receiving Prescription, Data Entry, Filling, Checking, Dispensing, Patient Counseling, Management, Inventory Management, Personal, Idle, Miscellaneous
  - Pilot test
  - Determine sample size
  - Collect data
  - Analyze data

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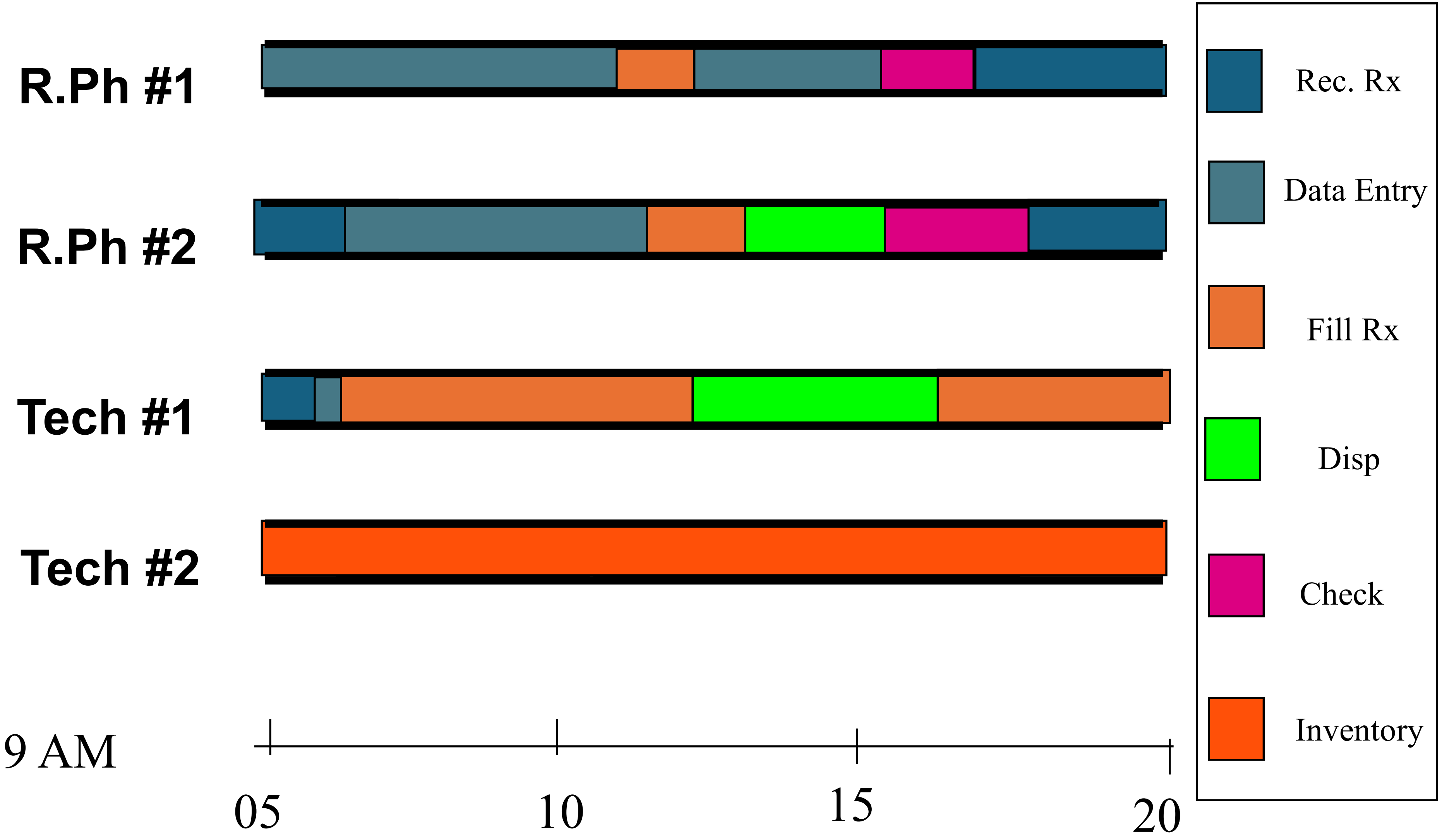
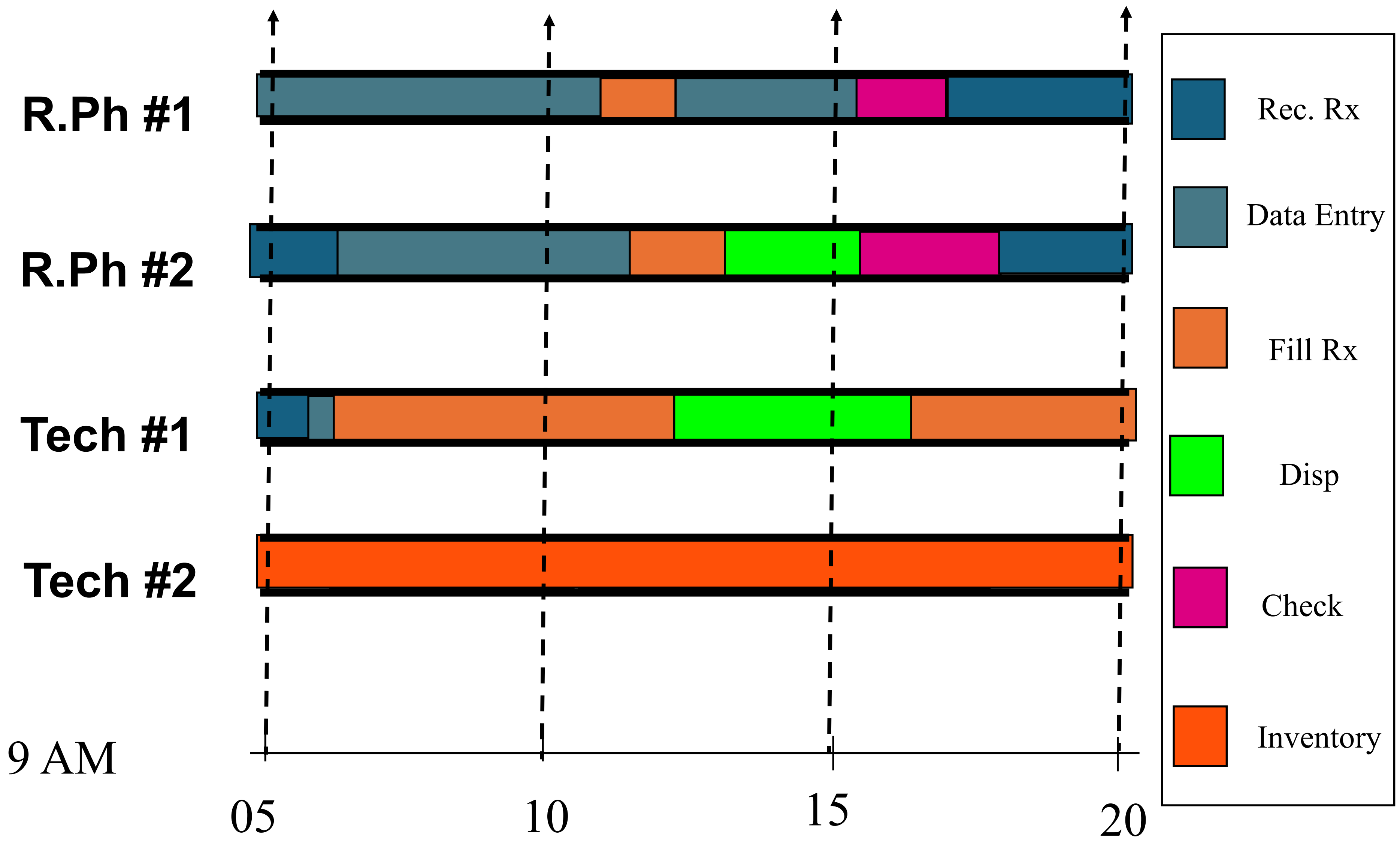
Randomness of Pharmacy Activities



Improved Work Sampling:
Fixed Time Interval Work Sampling



Benefits of Work Sampling

- Determine the effectiveness of staff utilization
- Determine the improvement
  - Strategies
  - Priorities

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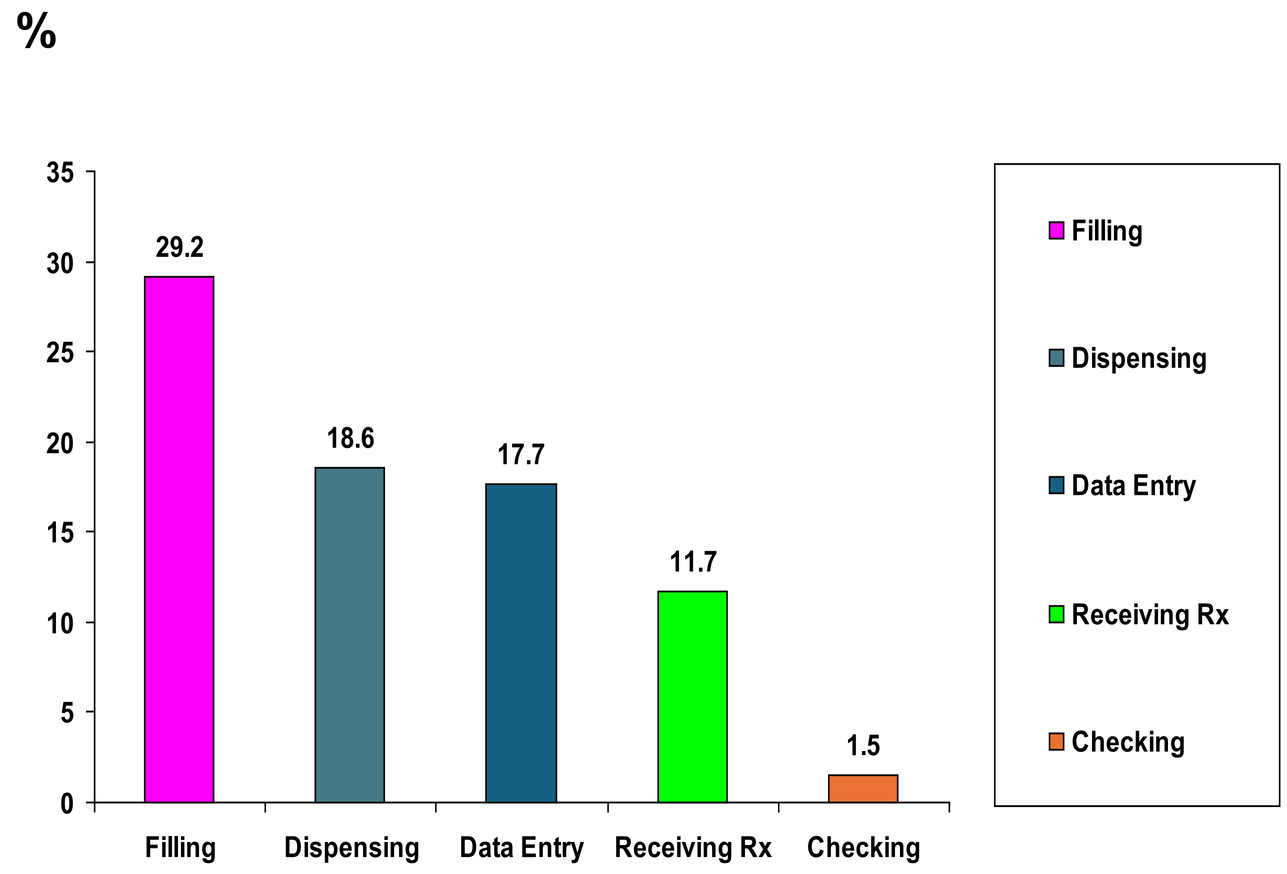
Pharmacy Staff Time Spent in a Major Chain Pharmacy (No Pill Counting Automation)



Stopwatch Study

- To quantify the duration of specific segments (efficiency)
- Steps
  - Determine the study objectives
  - Determine elements
  - Determine sample size
  - Collect data
  - Analyze data

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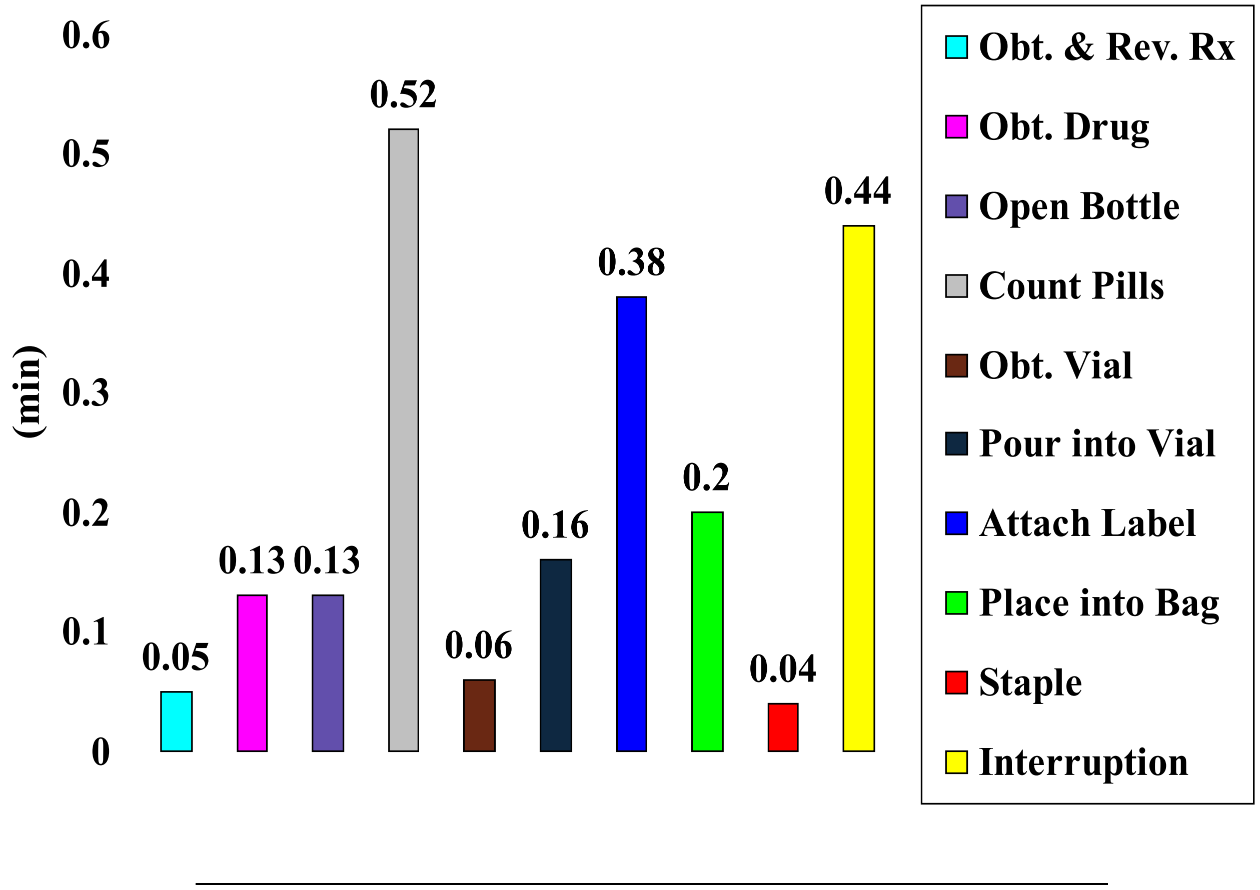
Response Time Analysis for STAT, NOW AND ASAP Orders

LOCATION	STEP	PERCENT OF TOTAL INTERVAL **PROCESS**	**DELAY**	**TOTAL**
NURSING UNIT				
1. M.D. releases order	--Clerk notes order		14.8	
2. Clerk notes order	--Order in holding bin	1.8		
3. Order in holding bin	--Dispatch to pharmacy		9.5	
15. Med arrives on unit	--Med obtained		12.3	
16.Med obtained	--Give med to patient/place med in patient drawer	0.7		
		2.5	**36.6**	**39.1**
TRANSIT TIME				
4. Dispatch order from unit	--order arrives in pharmacy	7.4		
14.Dispatch med from pharmacy	--Med arrives on nursing unit	7.4		
		14.8		**14.8**
PHARMACY				
5. Order arrives in pharmacy	--Order timed		15.5	
6. Order timed	--Order arrives keying area	2.8		
7. Order arrives keying area	--Start to punch order		9.2	
8. Start to punch order	--Label torn from printer	7.4		
9. Label torn	--Med in “to be checked” bin	2.8		
10. Med. in “to be checked” bin	--Rx obtains med		2.1	
11. Rx obtains med	--Med in “checked” bin	0.4		
12. Med in “checked” bin	--Pick up med checked		0.7	
13. Pick up med checked	--Dispatch med to nursing unit		5.3	
		13.4	**32.8**	**46.2**

Based on 28.4 min. for total interval

Results of Stopwatch Study: Filling Prescription (No Pill Counter)

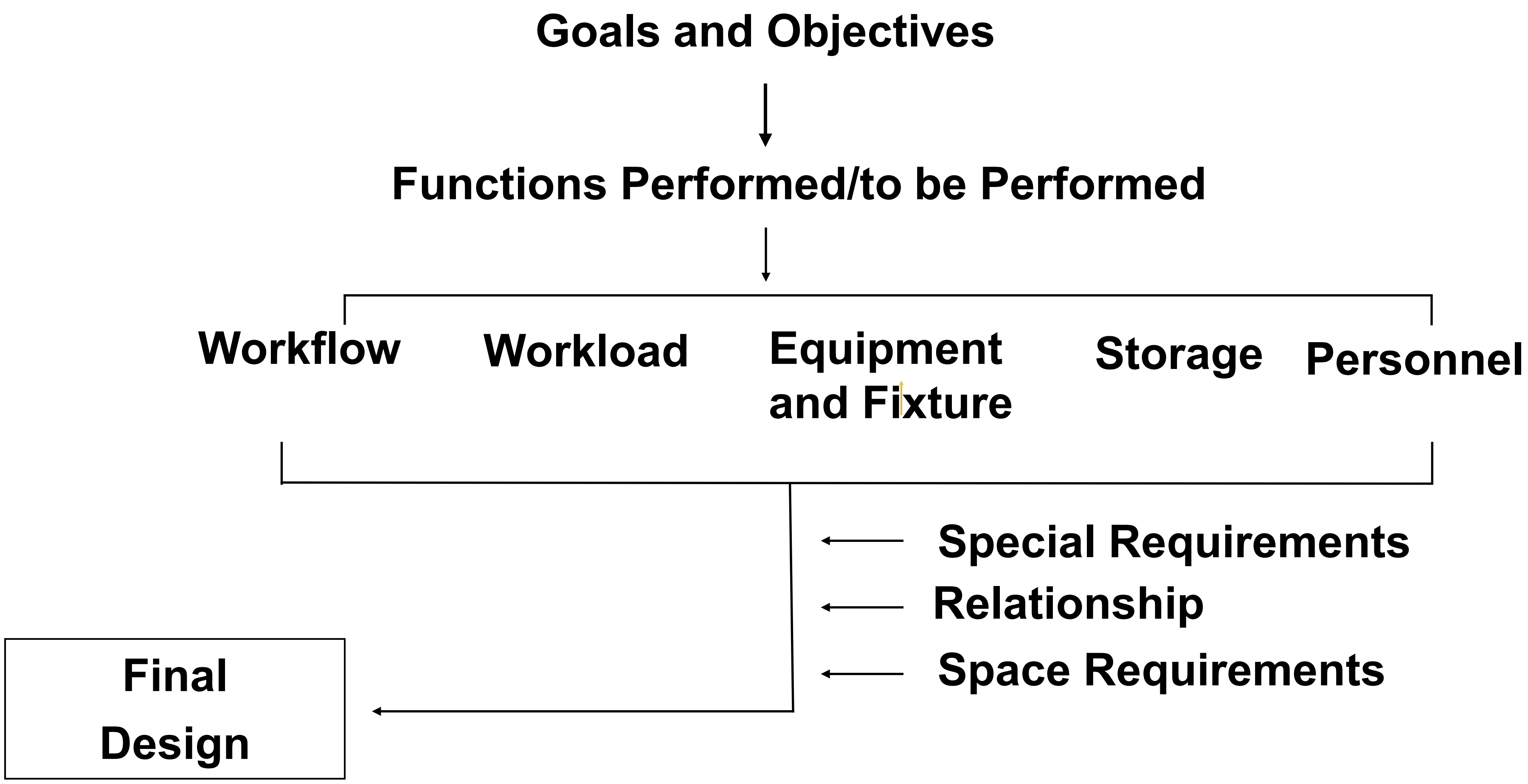


Faculty Design - Functional Programing

- A critical initial planning process that outlines the purpose and key requirements of a construction project.
- The document serves as a guide to ensure that the facility meets the owner's needs and functions as intended once completed.
- Key concept - Form Follows Functions.

Functional Programming

Form Follows Functions



Barker KN, Allan EL, **Lin AC**, et al. Chapter 17: Facility Planning and Design. In: Handbook of Institutional Pharmacy Practice, 3rd edition, Bethesda, MD: the American Society of Hospital Pharmacists, Inc. 1991; pp: 149-163.

Contents of Functional Program

- Goals and design assumptions
- Functions performed in pharmacy
- Workflow analysis
- Workload analysis
- Equipment and fixture analysis
- Storage analysis
- Personnel and special requirement analysis
- Function areas relationship analysis
- Space determination
- Schematic plans

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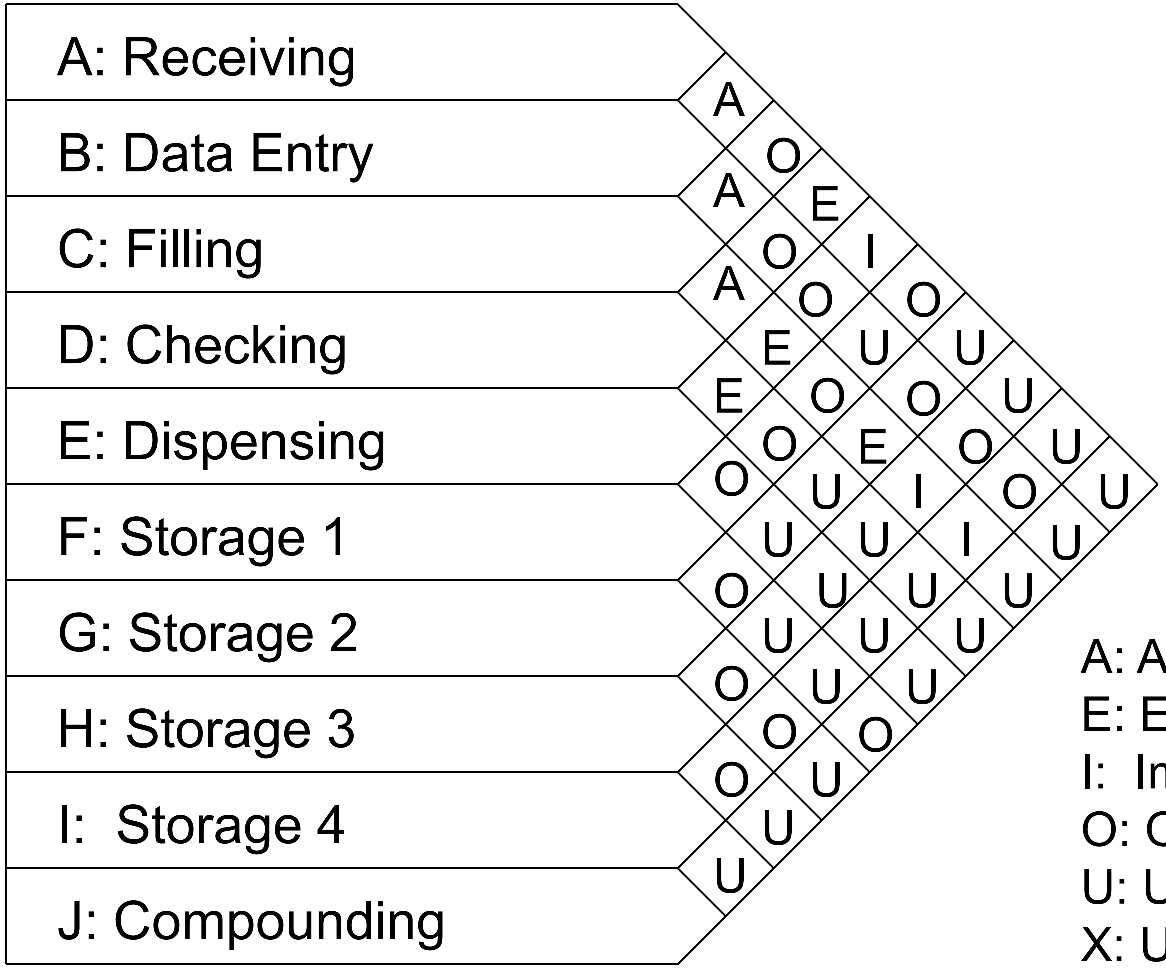
Function Areas Relationship Analysis

Factors to be considered:

- Workflow
- Points of input & output
- Access to fixed or shared equipment
- Need for frequent consultation
- Visual supervision
- Site limitation

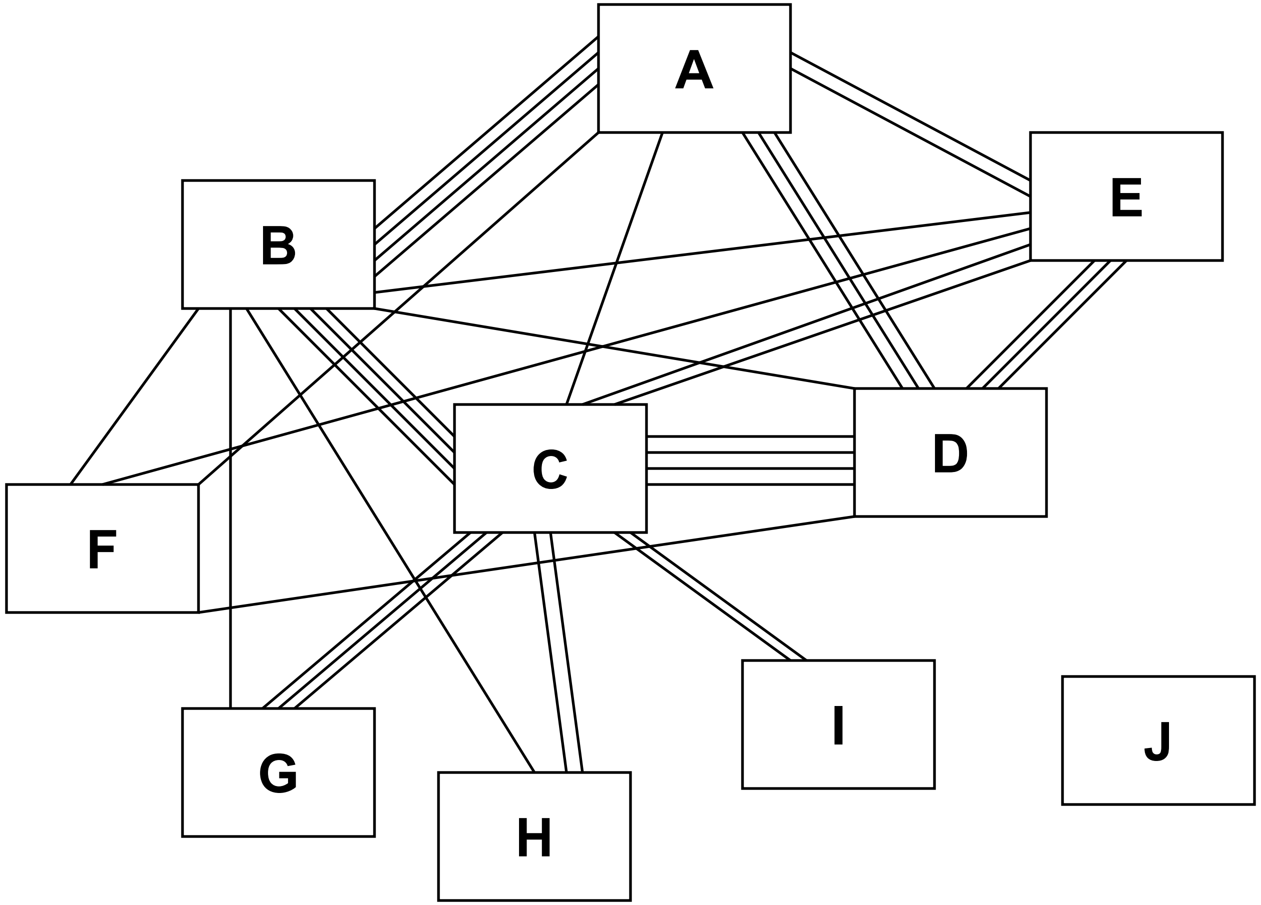
Activity Relationship Chart



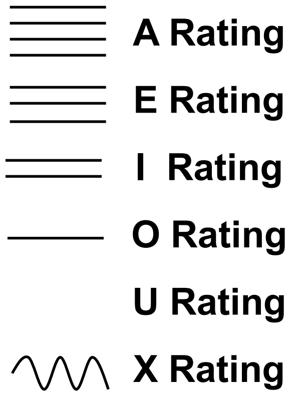
A: Absolutely necessary
E: Especially important
I: Important
O: Ordinary closeness OK
U: Unimportant
X: Undesirable

Activity Relationship Diagram

A: Receiving
B: Data Entry
C: Filling
D: Checking
E: Dispensing
F: Storage 1
G: Storage 2
H: Storage 3
I: Storage 4
J: Compounding



Legend



Personnel & Special Requirements

- Comply with regulations
  - State board
- Special requirements include
  - Utility
    - Power outlets
    - Water – cold, hot, distilled
  - Communications
  - Security
  - Others

Background
– The Christ Hospital Central Pharmacy

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Background
– Automated Systems (cont'd)

- Robot XR2 Automated Central Pharmacy System
- Carousel

Existing Robot Rx

New Robot XR2

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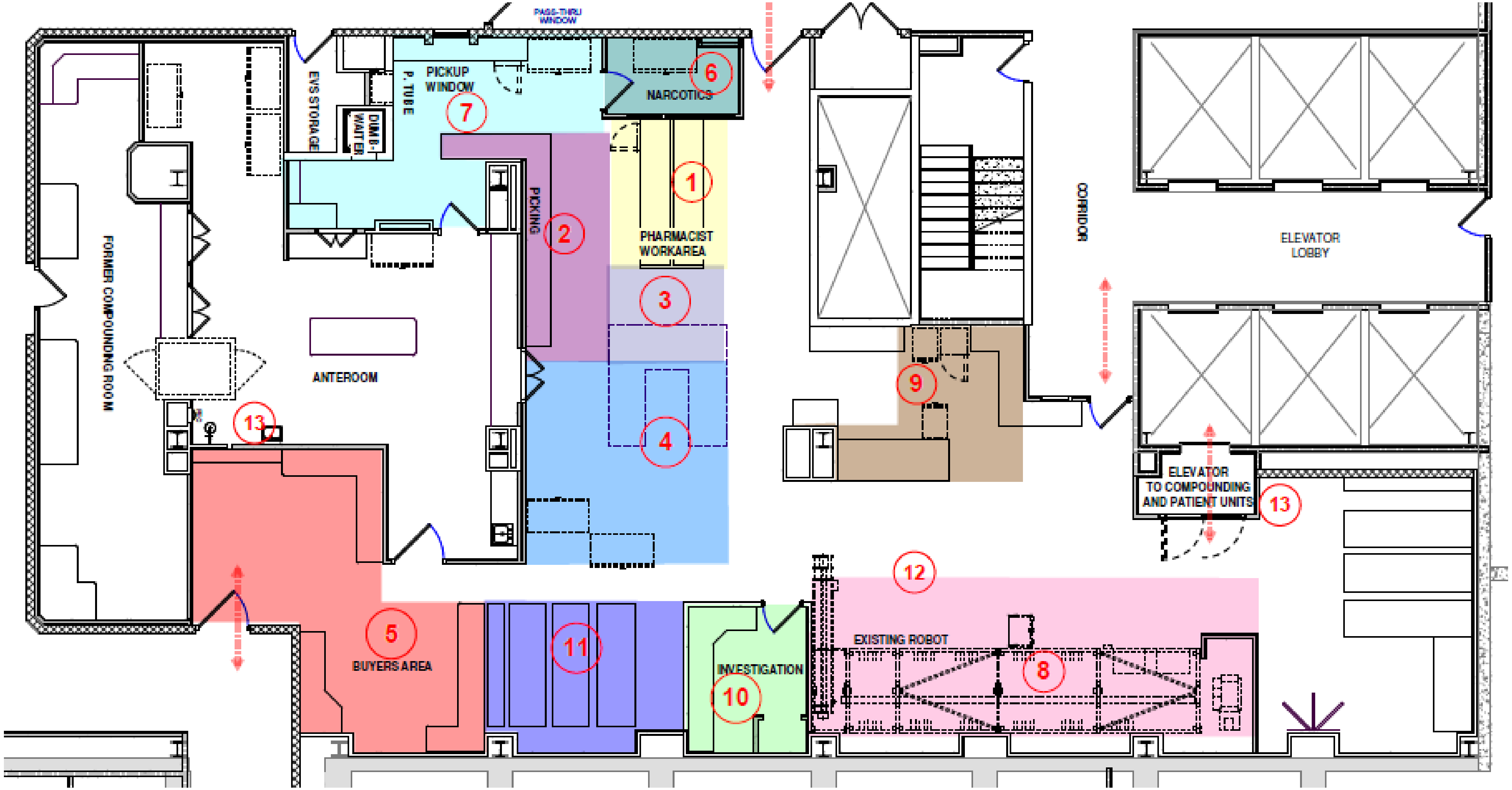

1. Order verification (OV)
2. Working station 1(WS)
3. Working station 2
4. Drug cabinet (DC)
5. Inventory (IN)
6. Narcotic (NR)
7. Window (WN)
8. Robot (RB)
9. Kitcheck (KT)
10. IND room
11. Storage
12. Circulation
13. Sink

Existing Work Areas

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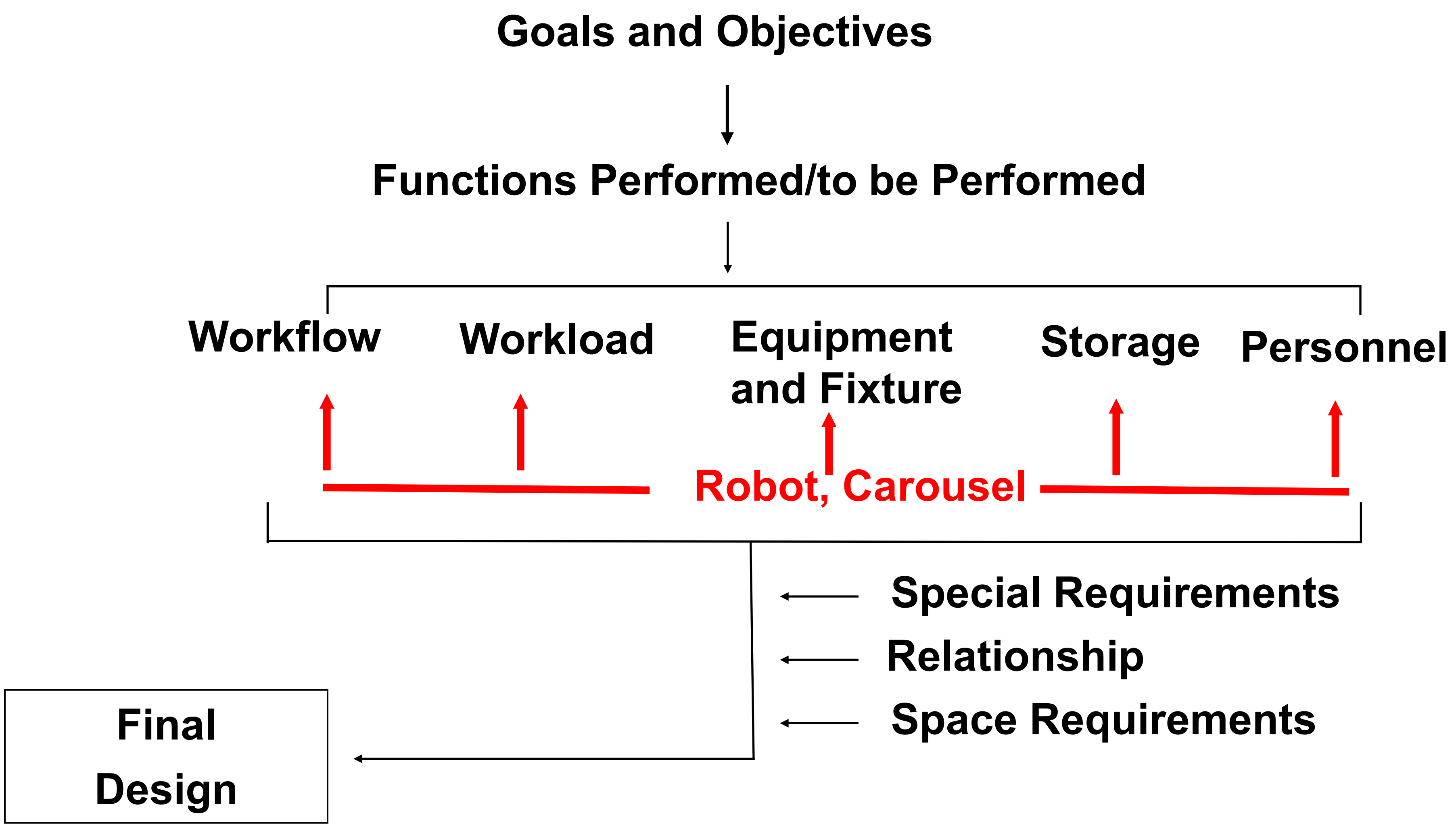
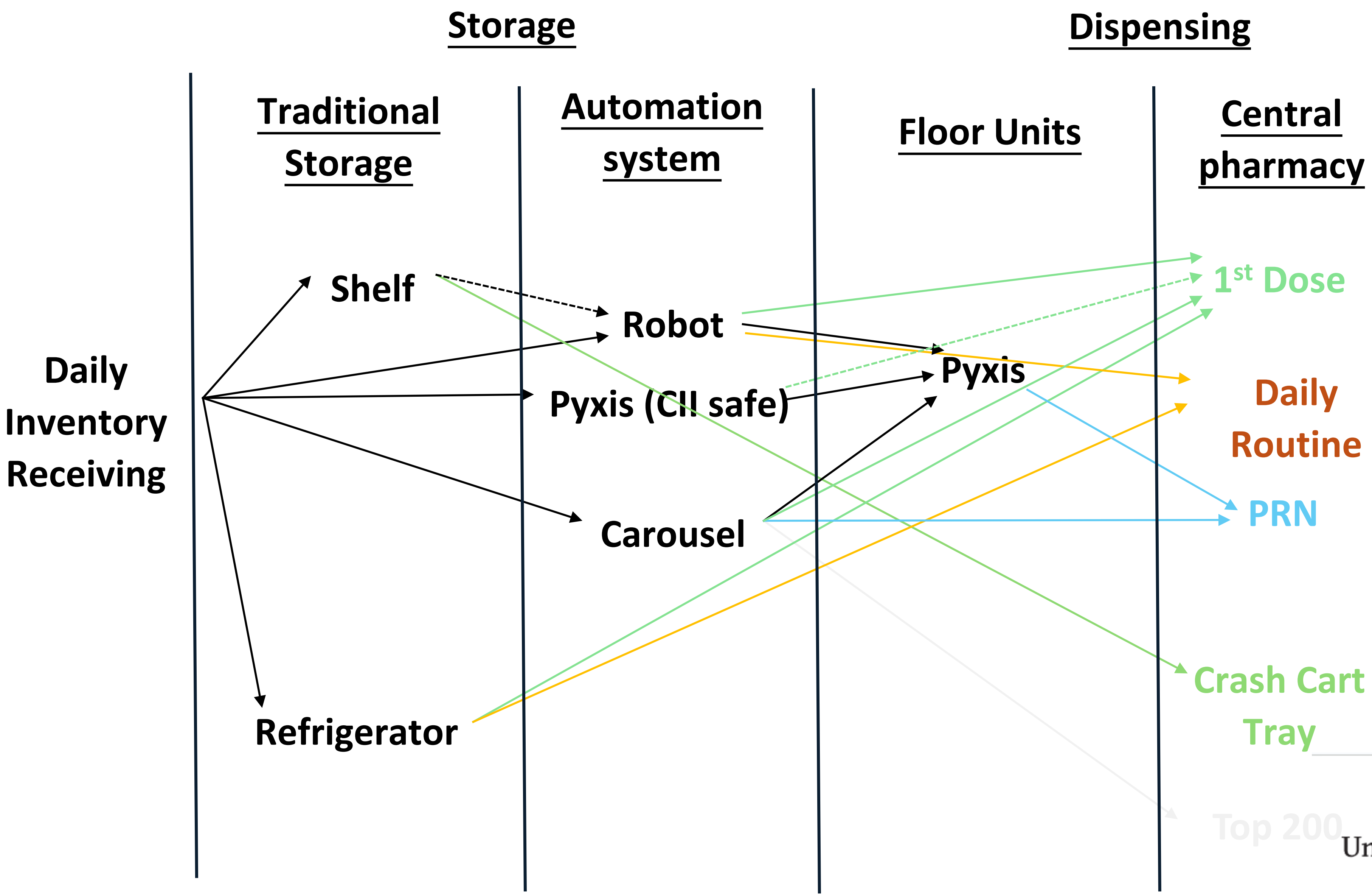
Functional Programming

Form Follows Functions



Storage and Inventory Analysis



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Indoor Tracking Technology

Ultra Wideband (UWB)

"A Radio Frequency signal occupying a portion of the frequency spectrum that is greater than 20% of the center carrier frequency, or has a bandwidth greater than 500 MHz"

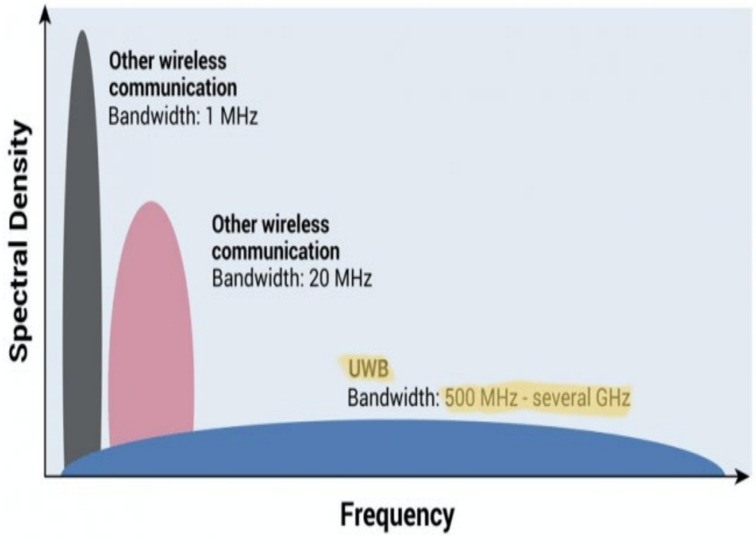

Image 1: Spectral density for UWB and narrowband

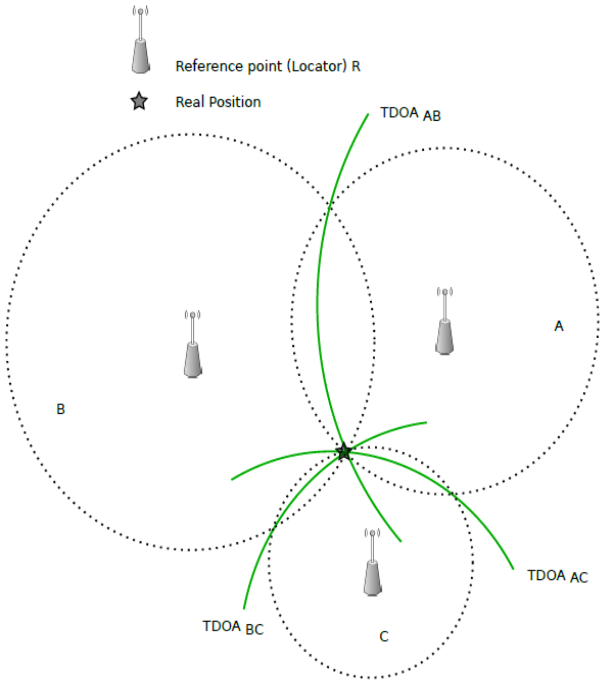

Figure 6. Time difference of arrival (TDoA)-based algorithms.

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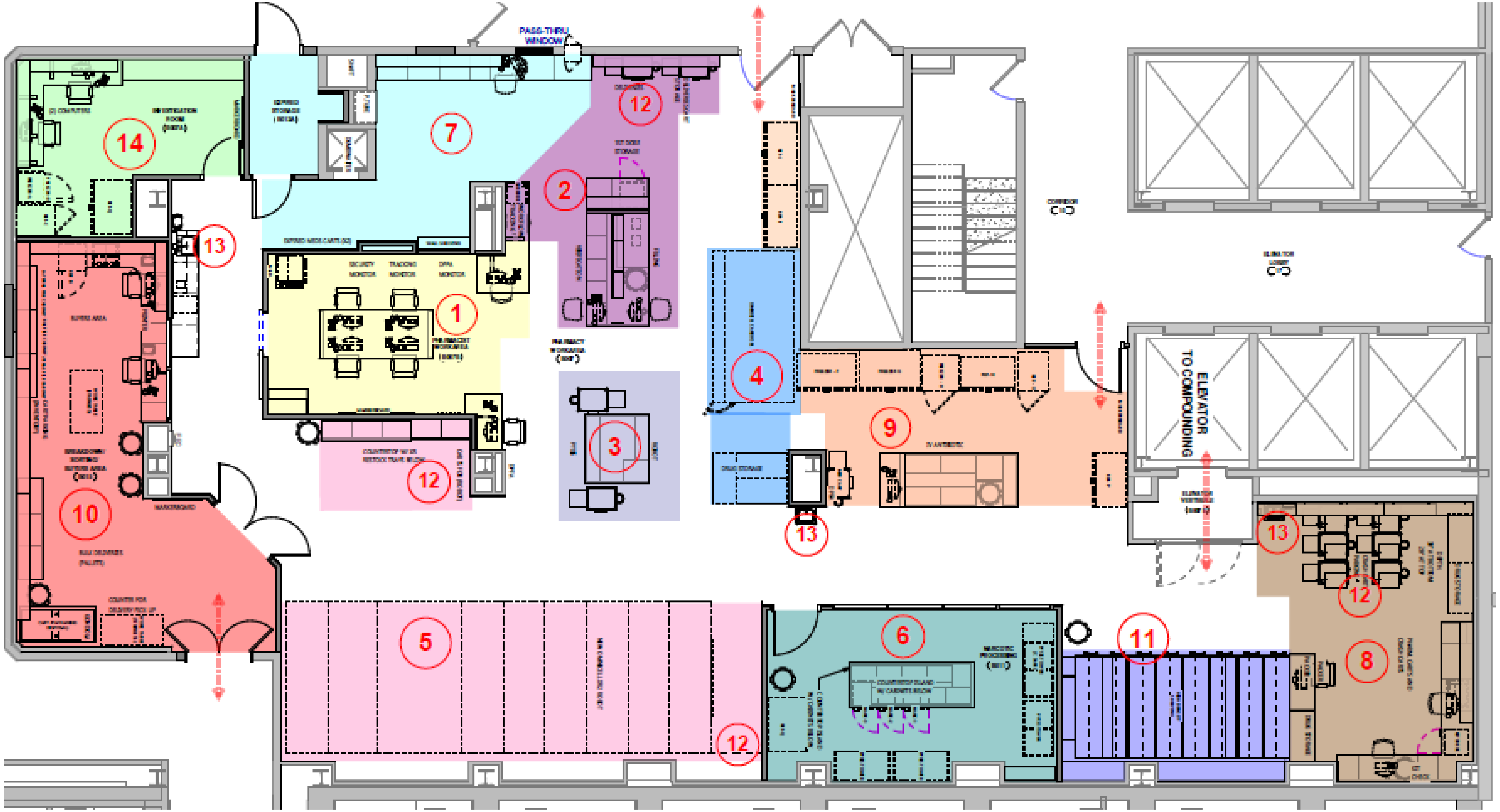

New Work Areas

1. Order verification
2. Working station 1
3. Working station 2
4. Carousel
5. Robot
6. Narcotic Room
7. Receiving Window and Tube Station
8. Crash cart
9. IV antibiotic
10. Inventory
11. Storage
12. Cart Parking
13. Sink
14. Investigational Room

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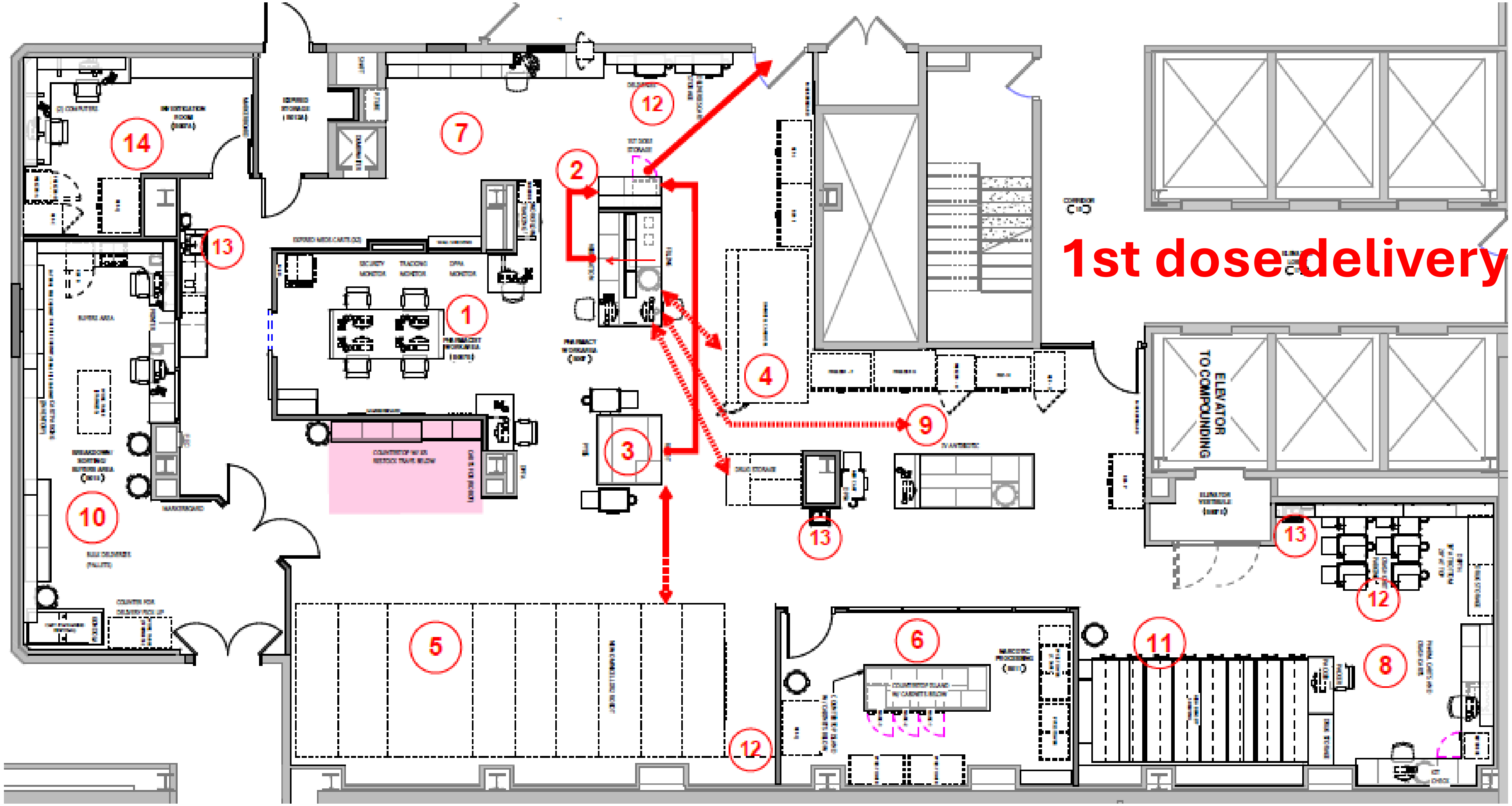

1. Order verification
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9. IV antibiotic
10. Inventory
11. Storage
12. Cart Parking
13. Sink
14. IND Room

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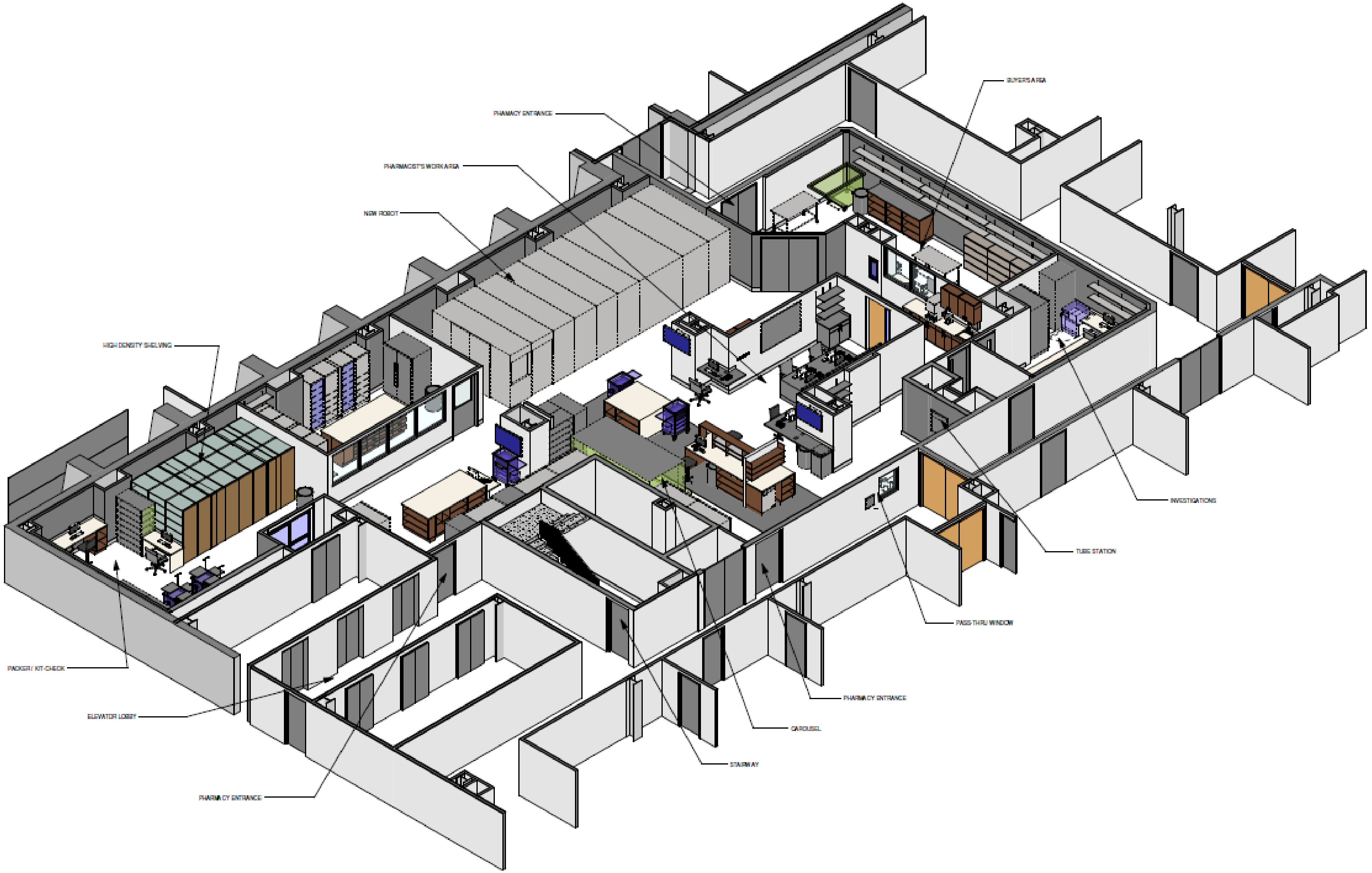
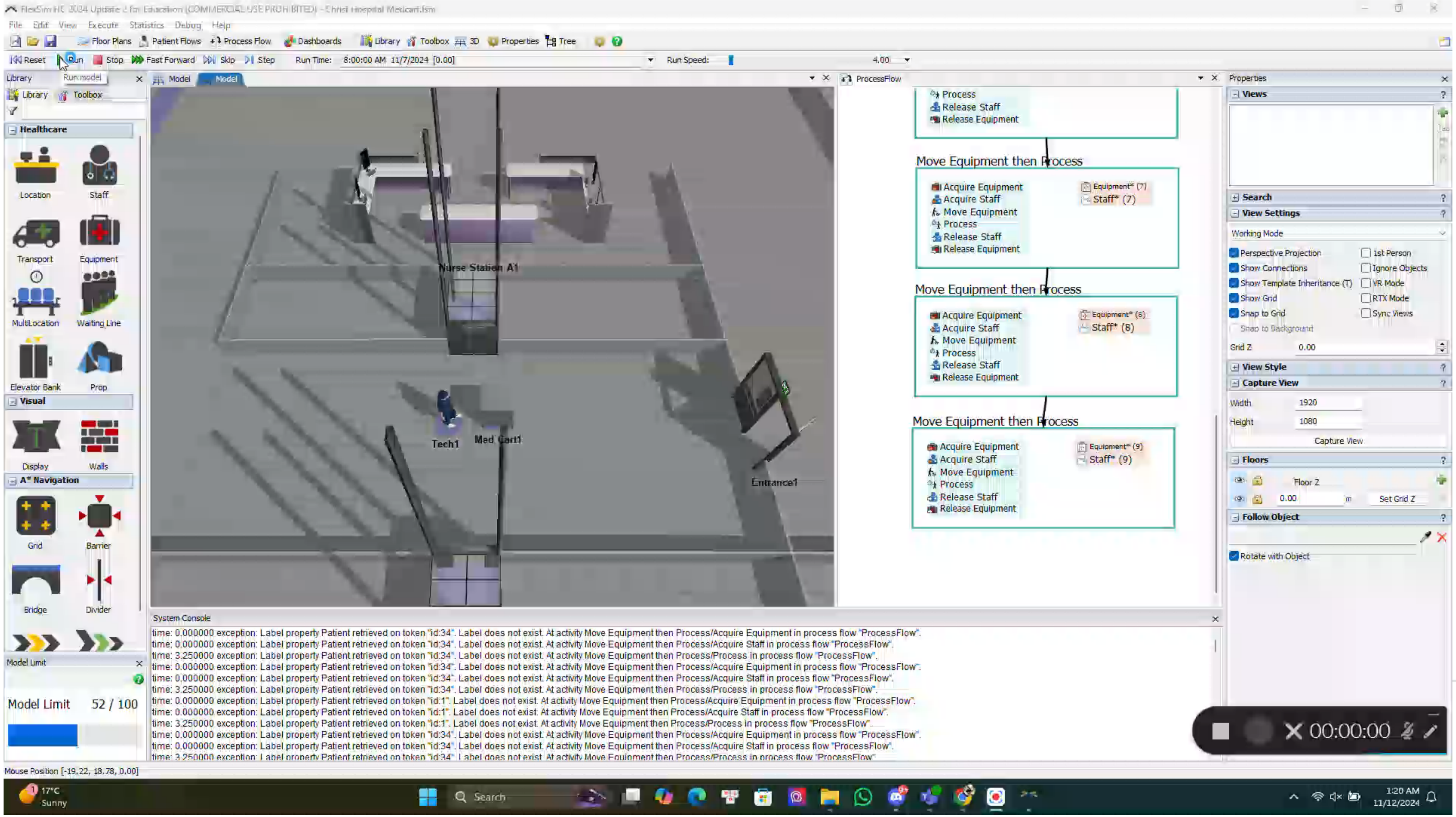


PHARMACY 3D PLAN - NORTHWEST VIEW

Computer Simulation

- A computer simulation is a digital model that represents the behavior of a real-world or hypothetical system.
- By running this model on a computer, we can study how the system behaves under various conditions without having to experiment in the real world.
- Key concept: generate behavior based on statistic and random number, e.g., arrivals of orders, time spent
- Approach:
  - Proposed the objectives
  - Workflow analysis
  - Data collection: computer data, time data
  - Implement in a simulation app
  - Validation
  - Test alternatives

Example of Computer Simulation



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New Paradigm – Pharmacy 5.0

- **Pharmacy 5.0, in alignment with Industry 4.0/5.0 principles, is a platform to explore Pharmacy 5.0 innovations to accelerate the development and implementation of new paradigms/technologies for large-scale pharmacy services in the US and across the world.**

Lin AC*, Lee J, Gabriel M, Arbet RN, Ghawaa Y, Ferguson A. The Pharmacy 5.0 Framework: A New Paradigm to Accelerate Innovation for Large-Scale Personalized Pharmacy Care. American Journal of Health-System Pharmacy (AJHP). 2024. 8(5); 141-147. https://doi.org/10.1093/ajhp/zxad212

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Agenda

- Problems and challenges of the existing pharmacy care systems
- Industry 1.0 - 5.0 and Pharmacy 1.0 – 5.0
- The Pharmacy 5.0 framework
- Illustrate the Pharmacy 5.0 framework by three examples

COMMENTARY

The Pharmacy 5.0 framework: A new paradigm to accelerate innovation for large-scale personalized pharmacy care

Am J Health-Syst Pharm. 2024;81:e141-e147

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medication therapy, resulting in an annual cost of $528 billion in hospitalizations and emergency room and physician visits in 2016 in the US.[1-3] Non-optimized medication therapy can manifest during a patient's journey through healthcare, from inappropriate diagnosis or prescribing to adherence issues or suboptimal therapeutic outcomes, and is a significant health challenge.[4] Despite the literature describing issues and solutions, sustained effective solutions have remained elusive.

An opportunity exists to address nonoptimized medication therapy and its challenges. Research has focused on segments within a patient's journey, such as providing the correct medication for a condition, evaluating its effects weeks later, overcoming barriers to adherence, and how providers impact adherence. There has been no overarching integrated framework to connect these segments while cohesively driving innovations in pharmacy.

Paradigm shift and framework are required. Pharmacy is continually aspiring to transform from the transaction-based business model of dispensing medications to a more interdisciplinary, patient-centric care model.[5] The aim of this integrated care technological and clinical advances, a paradigm shift and a framework are required to resolve professional and operational challenges.[6] The aim is to draw on the industrial revolution and develop similar processes in pharmacy.

Industrial revolution. The Industrial Revolution had 5 phases (Figure 1). Industry 1.0, the first industrial revolution, began in the mid-1700s as machinery, steam, and waterpower were applied to substitute human labor with more efficient machines. Industry 2.0 incorporated electricity and the adoption of assembly line concepts for mass production in the 1870s. Industry 3.0, known as the digital revolution, brought the application of computers, automation, and electronics to increase efficiency and quality beginning around 1970.[7] Manufacturing and distribution industries benefited from Industry 4.0 with the use of rapidly evolving technologies such as cyber-physical systems (CPS), the Internet of Things (IoT), artificial intelligence (AI), sensors, and object recognition in creating smart production. The emerging Industry 5.0 phase is embracing human-centric systems, in which human and smart systems work together more effectively and efficiently to maximize quality, service, and per-

Lin AC*, Lee J, Gabriel M, Arbet RN, Ghawaa Y, Ferguson A. The Pharmacy 5.0 Framework: A New Paradigm to Accelerate Innovation for Large-Scale Personalized Pharmacy Care. American Journal of Health-System Pharmacy (AJHP). 2024. 8(5); 141-147. https://doi.org/10.1093/ajhp/zxad212

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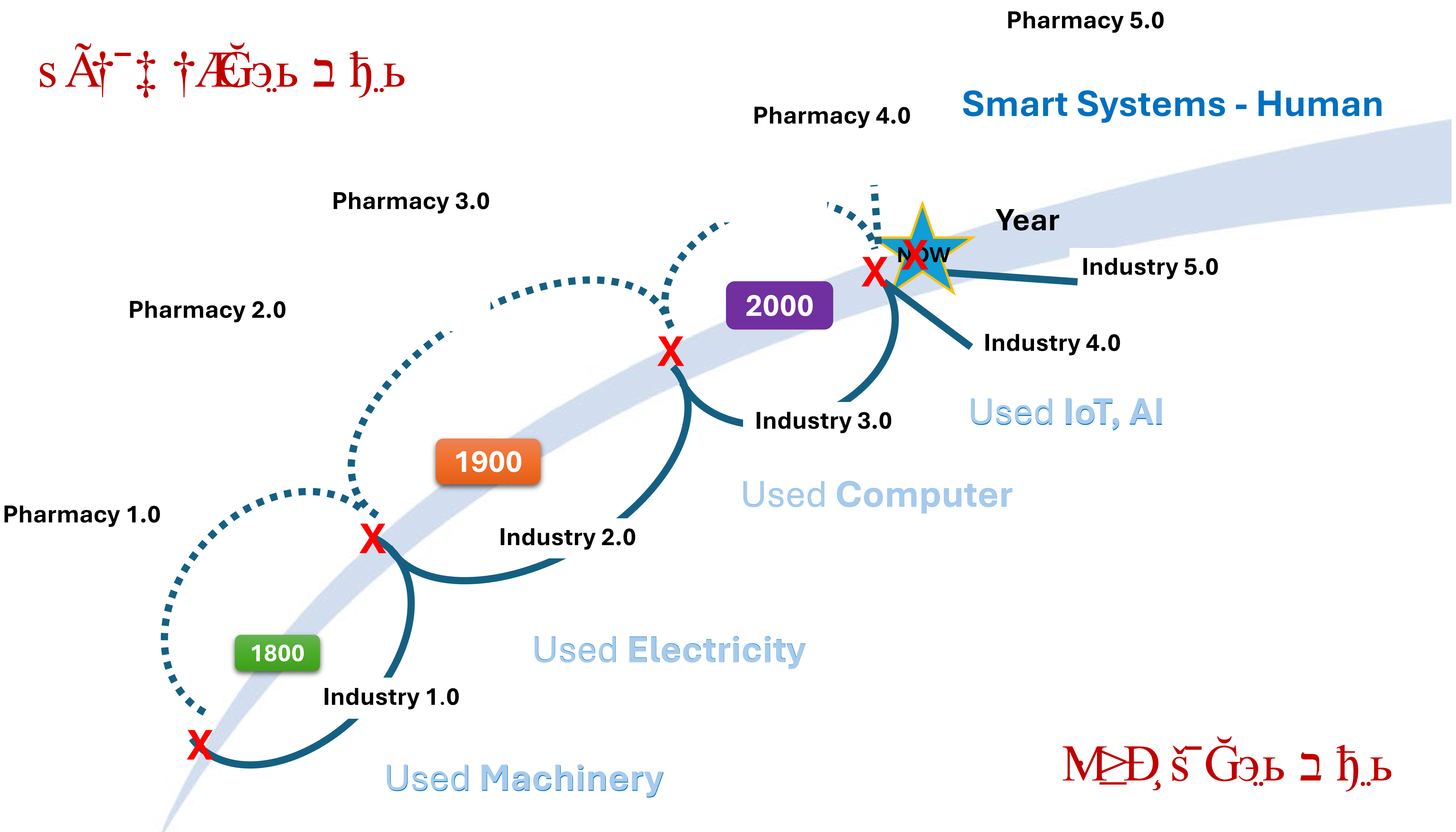
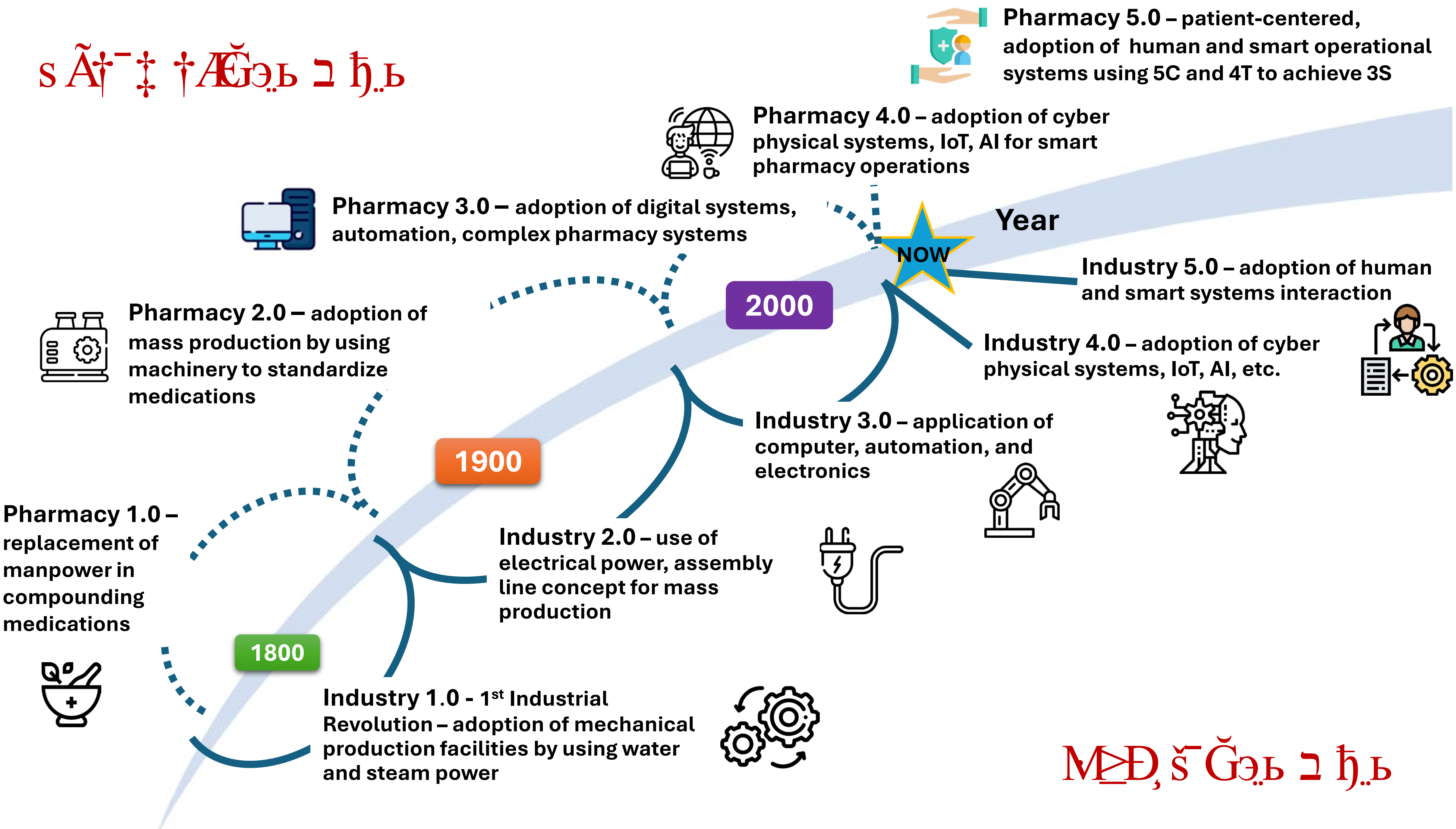

Pharmacy 5.0
Smart Systems - Human
Pharmacy 4.0
Pharmacy 3.0
Year
NOW
Industry 5.0
2000
Pharmacy 2.0
Industry 4.0
Used IoT, AI
Industry 3.0
1900
Used Computer
Pharmacy 1.0
Industry 2.0
Used Electricity
1800
Industry 1.0
Used Machinery


Pharmacy 5.0 – patient-centered, adoption of human and smart operational systems using 5C and 4T to achieve 3S
Pharmacy 4.0 – adoption of cyber physical systems, IoT, AI for smart pharmacy operations
Pharmacy 3.0 – adoption of digital systems, automation, complex pharmacy systems
Pharmacy 2.0 – adoption of mass production by using machinery to standardize medications
Pharmacy 1.0 – replacement of manpower in compounding medications
Year
NOW
2000
1900
1800
Industry 5.0 – adoption of human and smart systems interaction
Industry 4.0 – adoption of cyber physical systems, IoT, AI, etc.
Industry 3.0 – application of computer, automation, and electronics
Industry 2.0 – use of electrical power, assembly line concept for mass production
Industry 1.0 - 1st Industrial Revolution – adoption of mechanical production facilities by using water and steam power

Pharmacy 5.0: Aim and Goals

Aim

"To maximize medication distribution effectiveness and efficiency for transforming pharmacy to provide more clinical services and become health management centers"

Goals:

- To maximize:
  - Data visibility and integration
  - Medication safety
  - Operation/Distribution efficiency
  - Medication adherence
  - Therapeutic outcomes
  - Essential human intervention
  - Regulatory compliances
- To minimize:
  - Dispensing error
  - Medication error
  - Medication waste
  - Unplanned disruption
  - Non-essential/Routine human intervention

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Pharmacy 5.0 Framework: Overall Concept

- **Patient Centered** – patient and interprofessional care team through 5C and 4T to enhance 3S for patient care quality and efficiency
- **3S** (independently and collaboratively)
  - Smart Medication Safety – diagnosis, prescribing, and transcribing
  - Smart Pharmacy – operation and distribution logistics, supply chain
  - Smart Medication Adherence & Outcomes – adherence and outcomes
- **5C** - Cyber-physical system, Connection, Conversion, Cognition, and Configuration
- **4T** – Platform Technology, Data Technology, Analytical Technology, and Operation Technology
- Without 5C & 4T, 3S cannot be called ***Smart***

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Pharmacy 5.0 Framework (3S, 5C, & 4T)

Platform Technology

IT infrastructure

Cybersecurity

Data Technology

Acquire accurate, complete, and reliable data from various databases

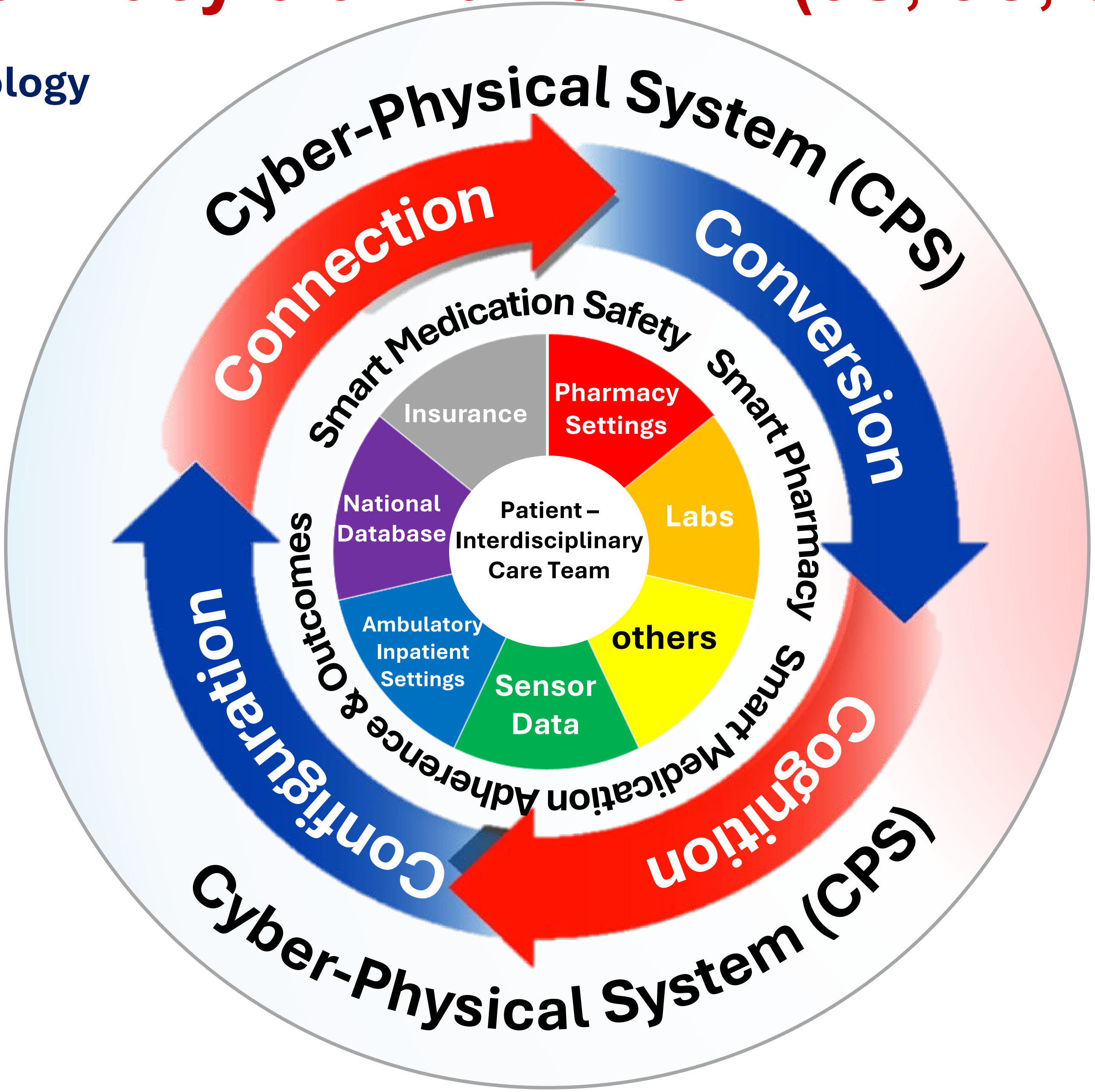
Operation Technology

Resilience control system

Self-configuration

Self-adaptive

Self-corrective



Meaningful information derived from the data

Analytical Technology

Generate proper presentation of the acquired knowledge to support the correct decisions

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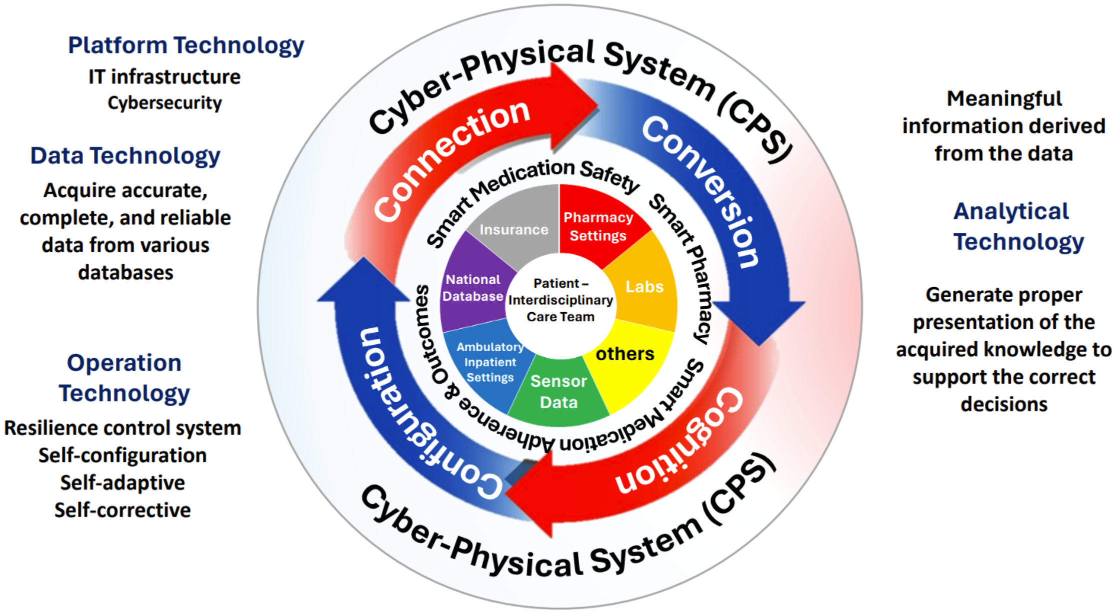
Pharmacy 5.0 Framework - Technology and Principles



Technology and Principles:

- Artificial Intelligence (AI)
- Machine Learning (ML)
- Internet of Things (IoT)
- Robotics
- Autonomous Mobile Robot (AMR)
- Augmented Reality (AR)
- Virtual Reality (VA)
- Drones
- 3D printing
- Digital twins
- Wearable
- Nanotechnology
- Quantum computing
- Pharmacogenomics
- Lean Six Sigma
- Facility design
- Computer simulation

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Healthcare Operational Excellence (HOPEX)

- Aim: to improve quality and efficiency in pharmacy and healthcare settings
- Based on the Pharmacy 5.0 framework*, initiated by the James L. Winkle College of Pharmacy, aligned with the principles of Industry 4.0/5.0.
- Involve with a variety of advanced technologies and concepts,
  - Lean Six Sigma I - Introduction to Lean Six Sigma
  - Lean Six Sigma II - Quality Management in Healthcare
  - Lean Six Sigma III - Standard Work & Sustainability
  - Machine learning, deep learning, artificial intelligence (AI), and big data analysis
  - Automation, robots, etc.

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Q & A

https://uconlinedev.wpengine.com/masters-programs/ms-pharm-sci-in-healthcare-operational-excellence/

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