

Don't let us ask for the Moon, we have automation!

Technologies to automate clinical workflow in radiation therapy

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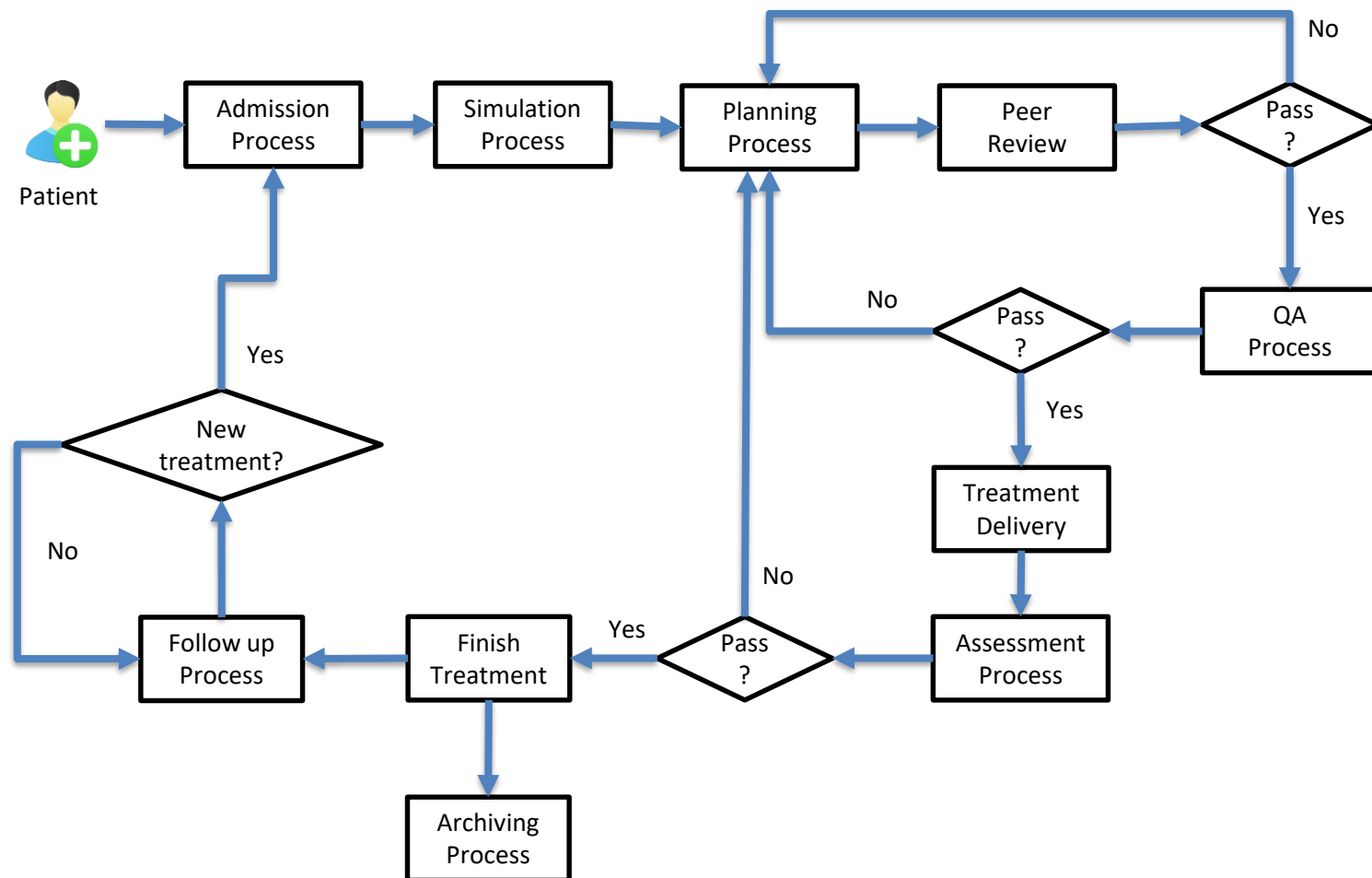
Learning objectives

1. Know what RTLS is, and how can RTLS technologies improve clinical workflow for higher operation efficiency, better patient safety and experience.
2. Know technologies to improve communications in clinic.
3. Know what DICOM and RT PACS are, and technologies to automate plan archiving.

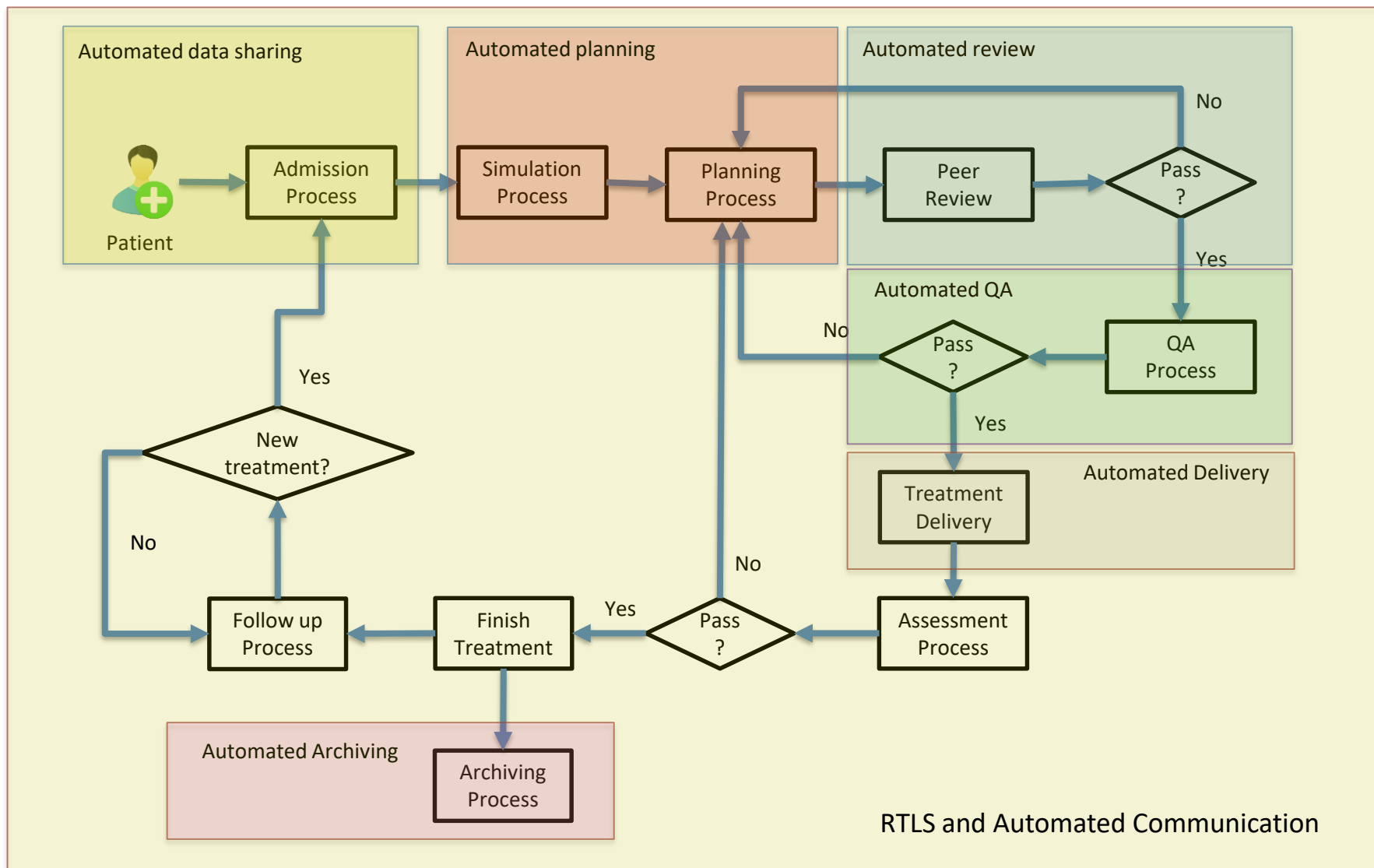
Outline

1. Clinical workflow and automation options.
2. Real-Time Location system and its applications in radiation therapy clinics.
3. Automated communications.
4. Automated chart rounds.
5. Automated plan archiving.

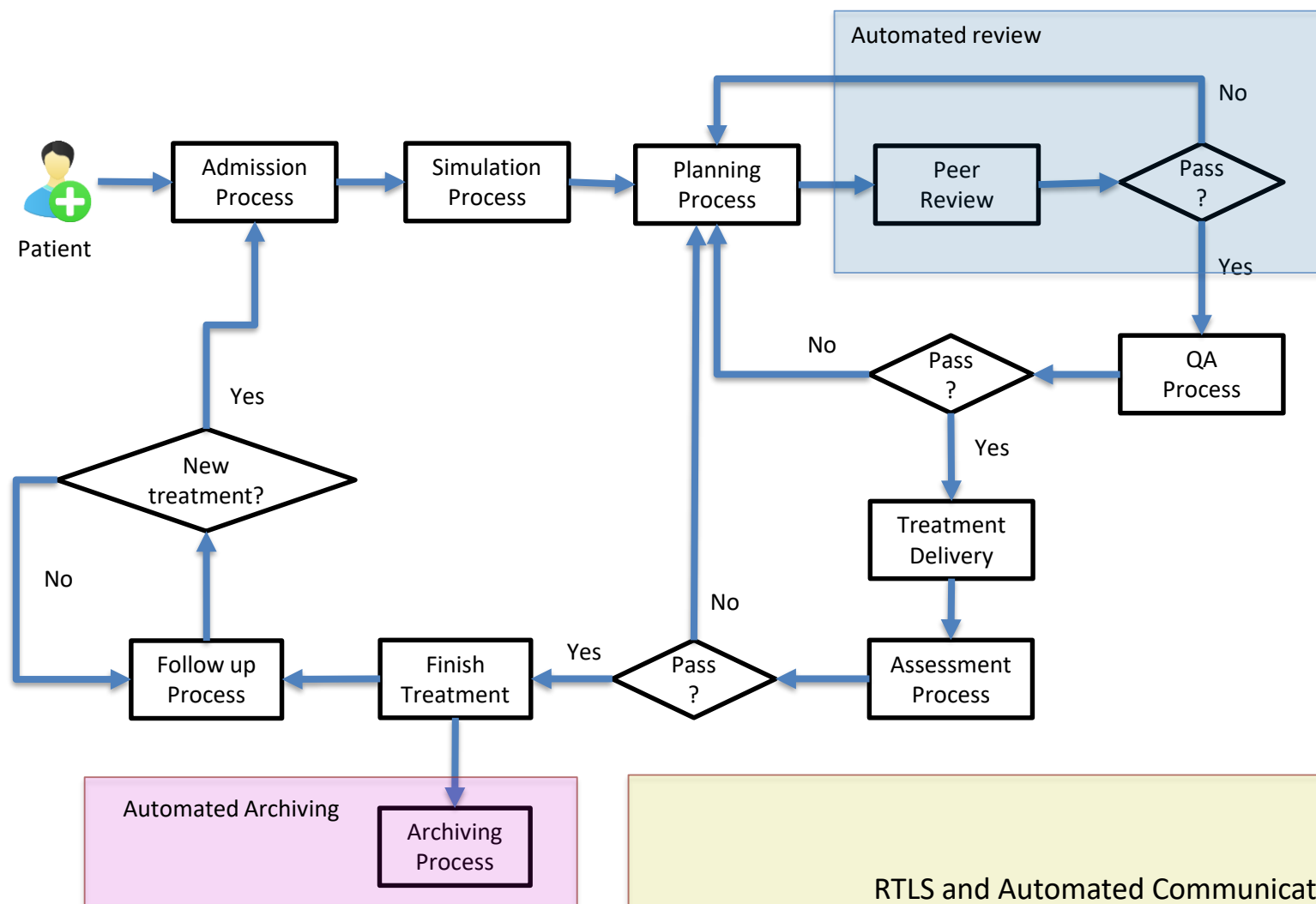
A typical clinical workflow



A typical clinical workflow



Automated portion to discuss



Real-Time Location System

Real-Time Location System (RTLS) is such a system that can tell the care team at any moment locations of patients, accessories, equipment and staff.

Why is RTLS useful ?

1. Track/verify patients
2. Track/verify patient-specific accessories
3. Track shared equipment
4. Track staff

RTLS technologies

1. Active radio frequency identification (active RFID)
2. Passive radio frequency identification (passive RFID)
3. Active radio frequency-infrared hybrid (active RFID-IR)
4. Infrared (IR)
5. Optical locating
6. Passive RFID RTLS via Steerable Phased Array Antennae
7. Ultrasonic ranging (US-RTLS)
8. Bluetooth Low Energy (BLE)
9. ...

BLE beacon and receiver

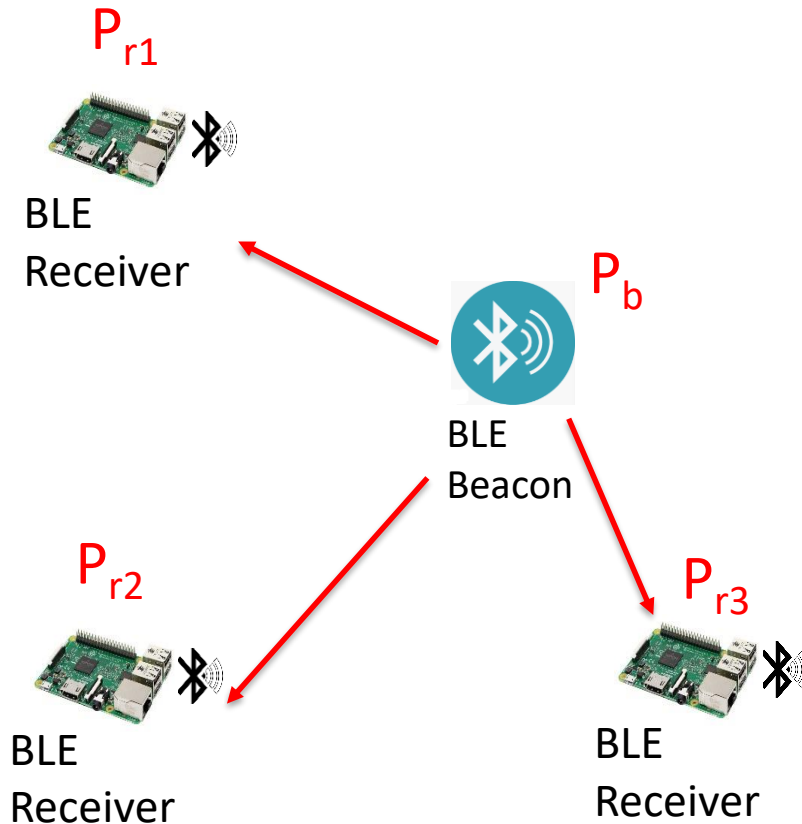
Form factors of BLE beacons



Raspberry Pi as BLE receiver

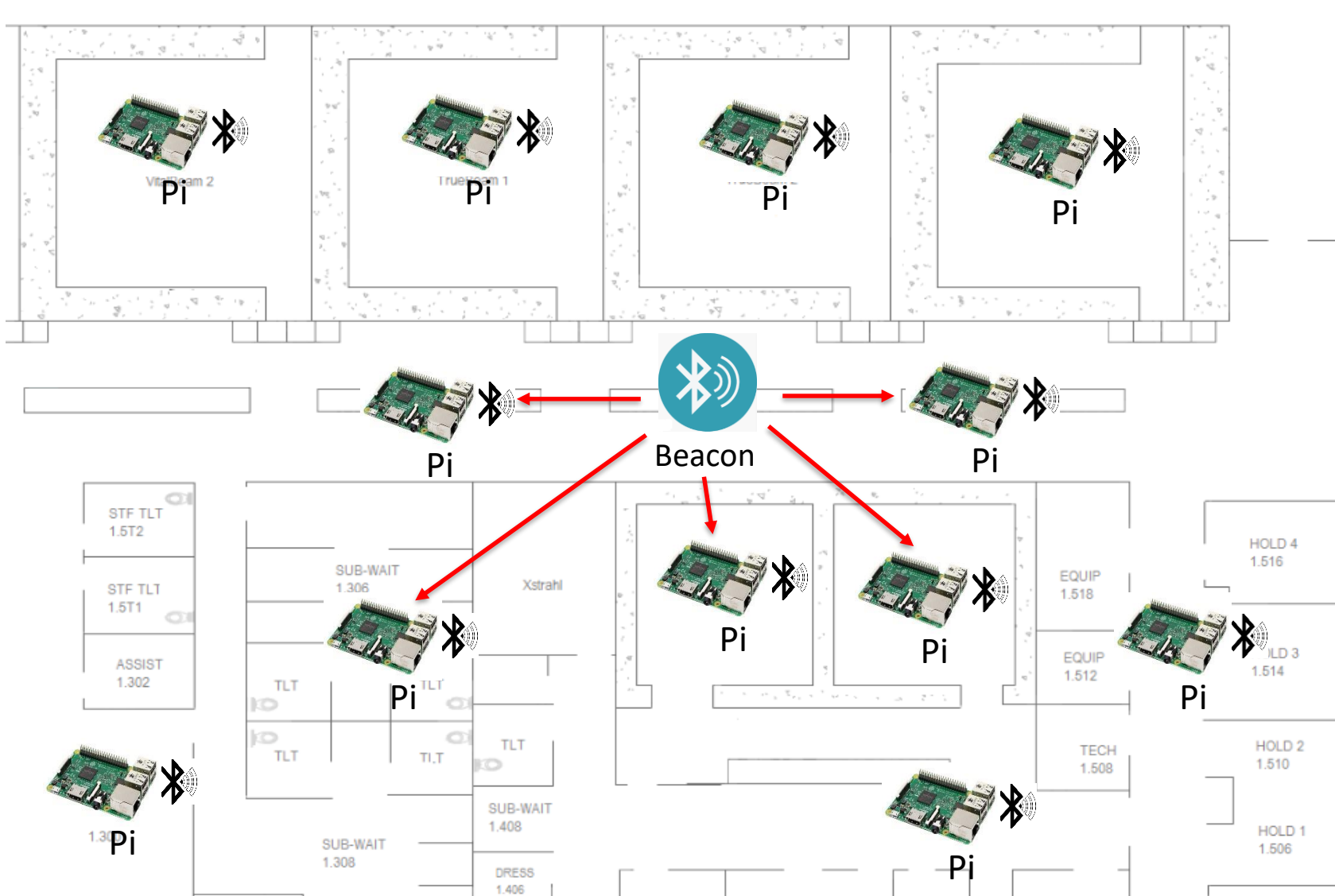


How does BLE RTLS work ?



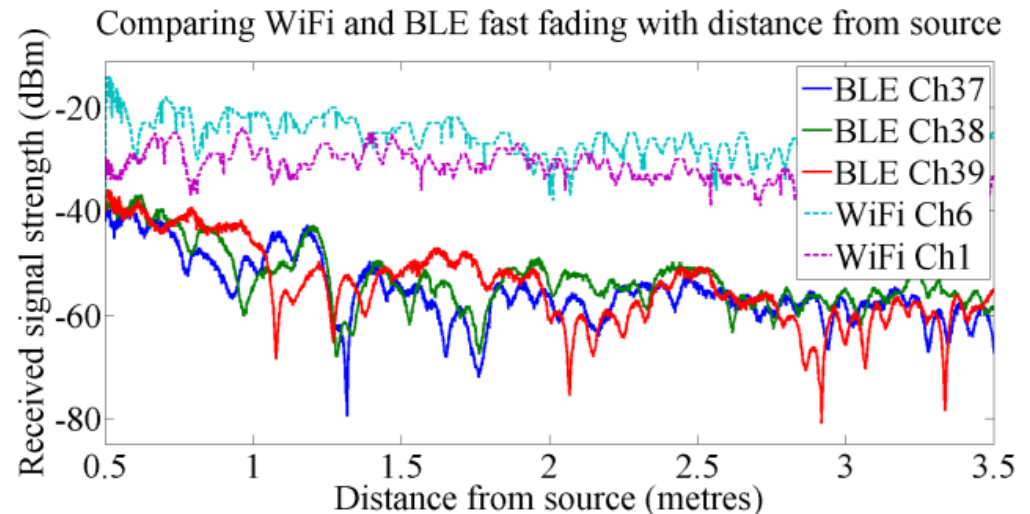
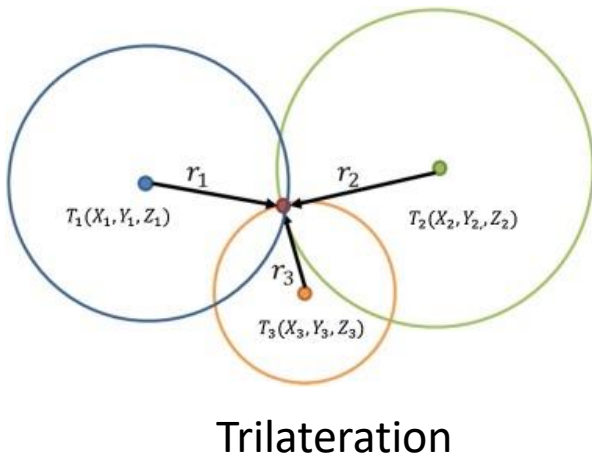
- A BLE beacon at a unknown point P_b sends RF pulse at an interval to all directions.
- BLE receivers at known locations (P_{r1} , P_{r2} , P_{r3}) receive RF signal at different strengths.
- Use an algorithm to estimate BLE beacon location P_b .

How does BLE RTLS work ?



Methods for location calculation

- **Traditional methods – Trilateration, threshold**
 - Suffer from low accuracy and stability
 - Signal strength is affected by building infrastructure
 - Signal is affected by strong interference (wavelength $\sim 12\text{cm}$)
- **Machine learning methods – ANN, CNN, RNN**



Faragher et al. 2014, Computer Science.

Bluetooth signal is highly fluctuated!

AI solved the problem



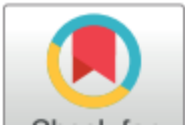
RESEARCH ARTICLE

Accurate real time localization tracking in a clinical environment using Bluetooth Low Energy and deep learning

Zohaib Iqbal , Da Luo, Peter Henry, Samaneh Kazemifar, Timothy Rozario, Yulong Yan, Kenneth Westover, Weiguo Lu, Dan Nguyen, Troy Long, Jing Wang, Hak Choy, Steve Jiang*

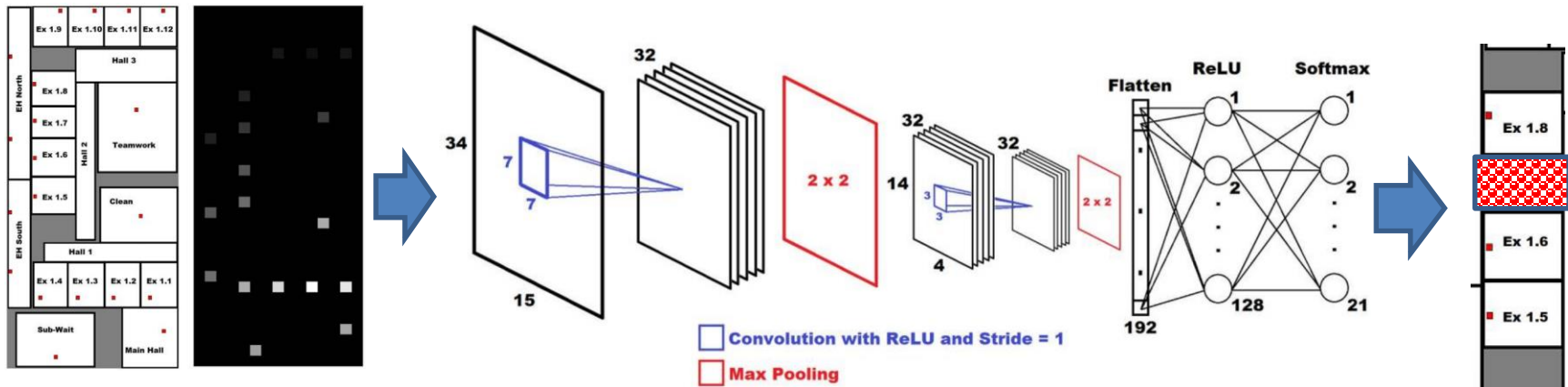
Medical Artificial Intelligence and Automation Laboratory, Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, TX, United States of America

* Steve.Jiang@utsouthwestern.edu



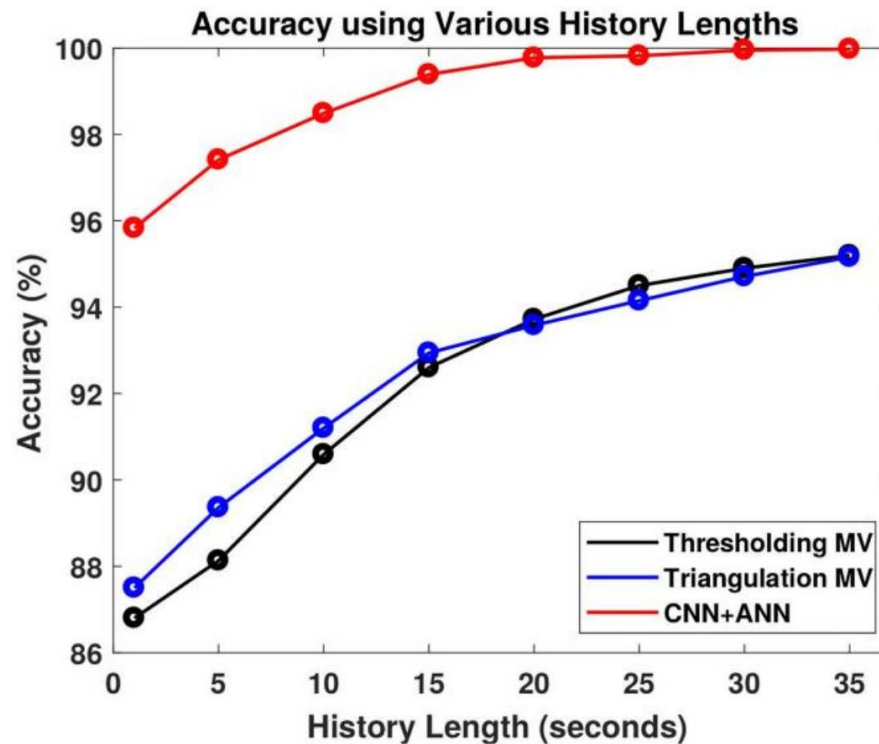
Find location in deep learning

- sensors (> 3) to calculate location
- Simulate effects of building structure and signal interference
- Train the DL database in calibration process (build location patterns)
- Find the closest pattern in the machine learning database



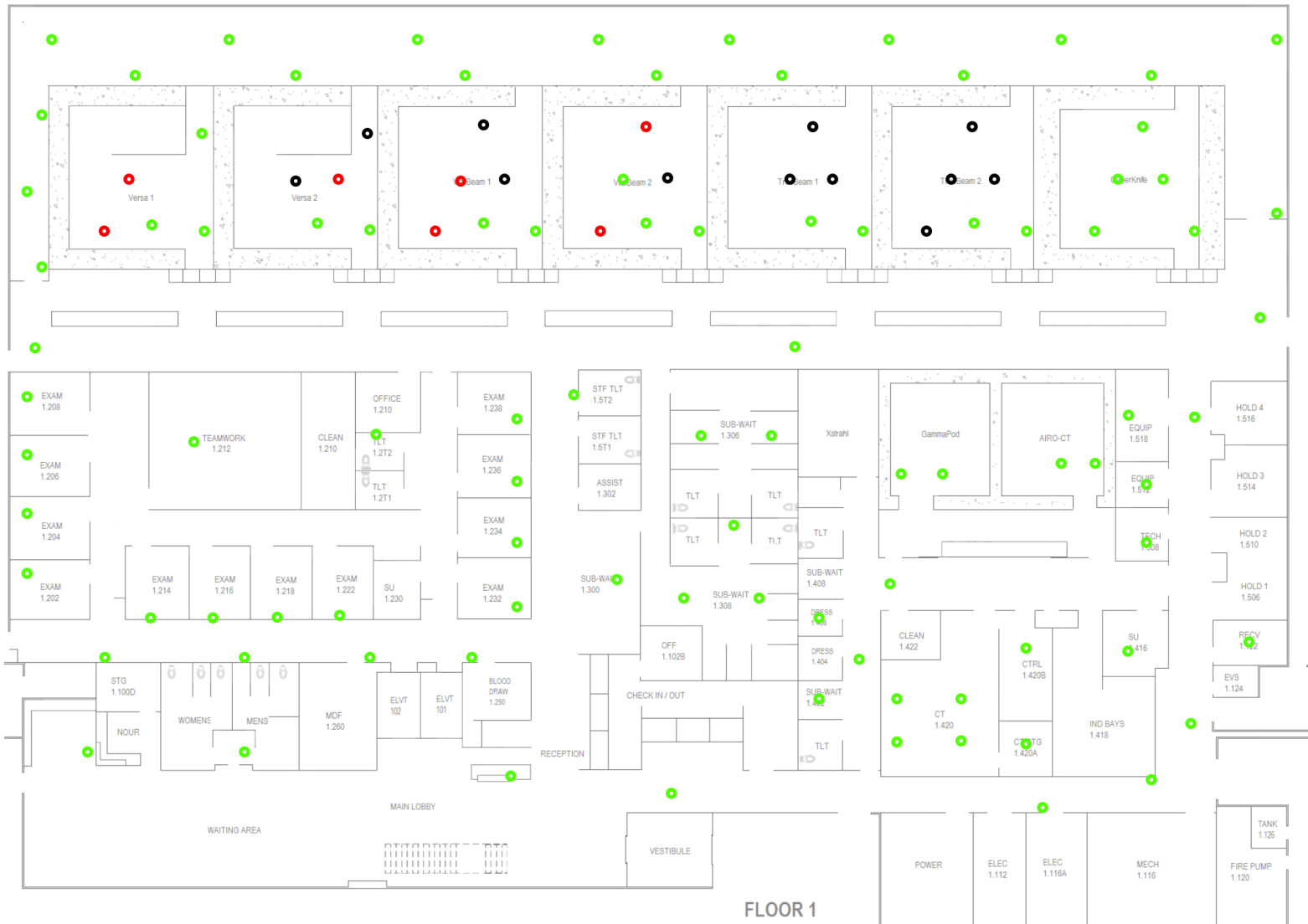
Iqbal et al. 2018, PLoS ONE

Deep Learning is more accurate than traditional methods

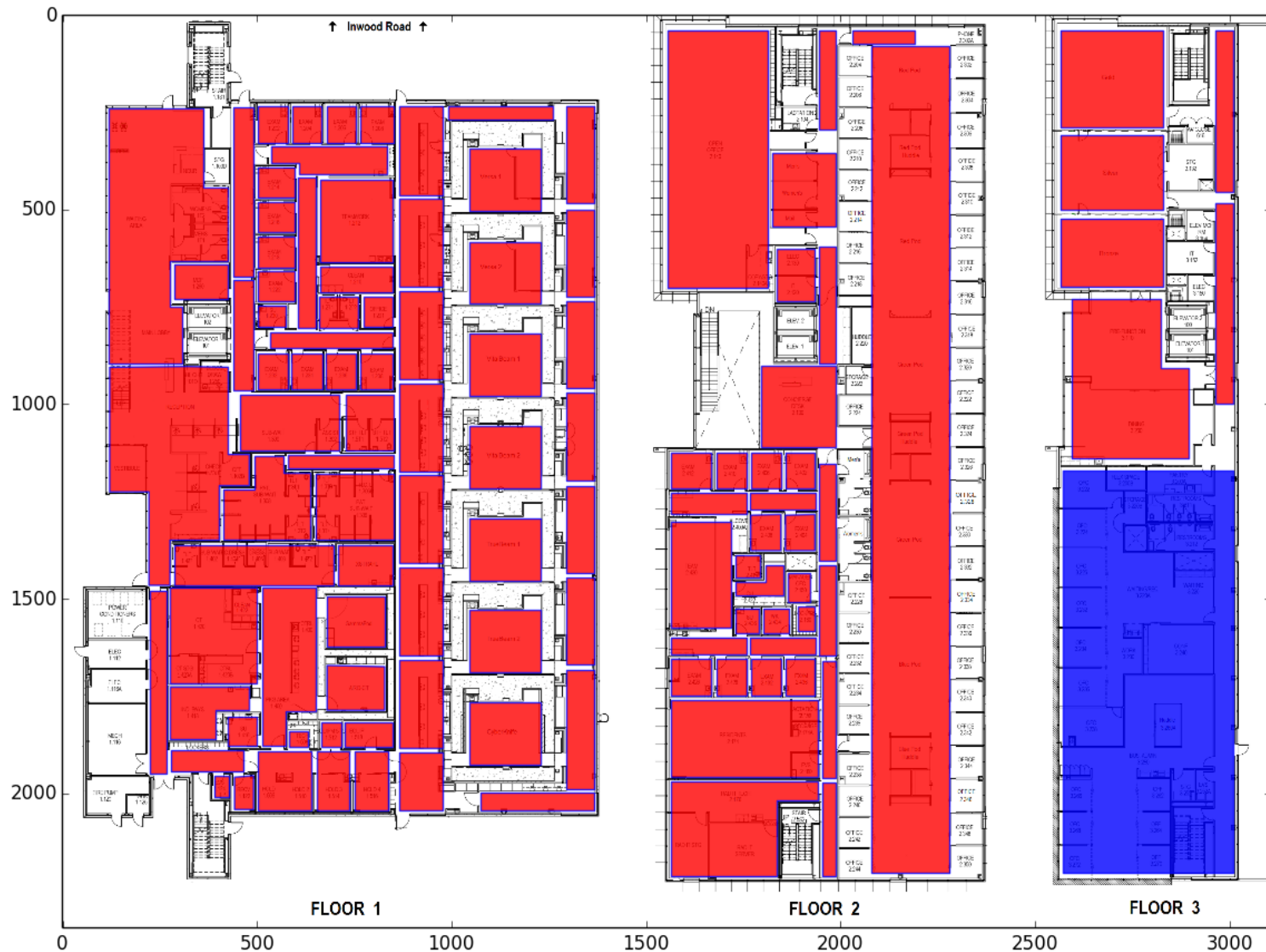


Iqbal et al. 2018, PLoS ONE

Locations of 133 Raspberry Pis



Building is divided into 144 zones



RTLS Applications

- **Tag registration and management**
- **Live Map**
 - Patient location
 - Device location
 - Accessory location
 - Staff location
- **Location “google”**
- **Electronic checklist**
 - Double check patient’s ID
 - Double check accessories
- **Timeboard**
- **Attendance auto check-in**
- **Patient auto check-in**

RTLS tag registration app

Tag Registration - Real Time Location System

Where

Live Map

Patient

Accessory

Staff

Equipment

Tag ID:

Patient:

Register

All

Not Present

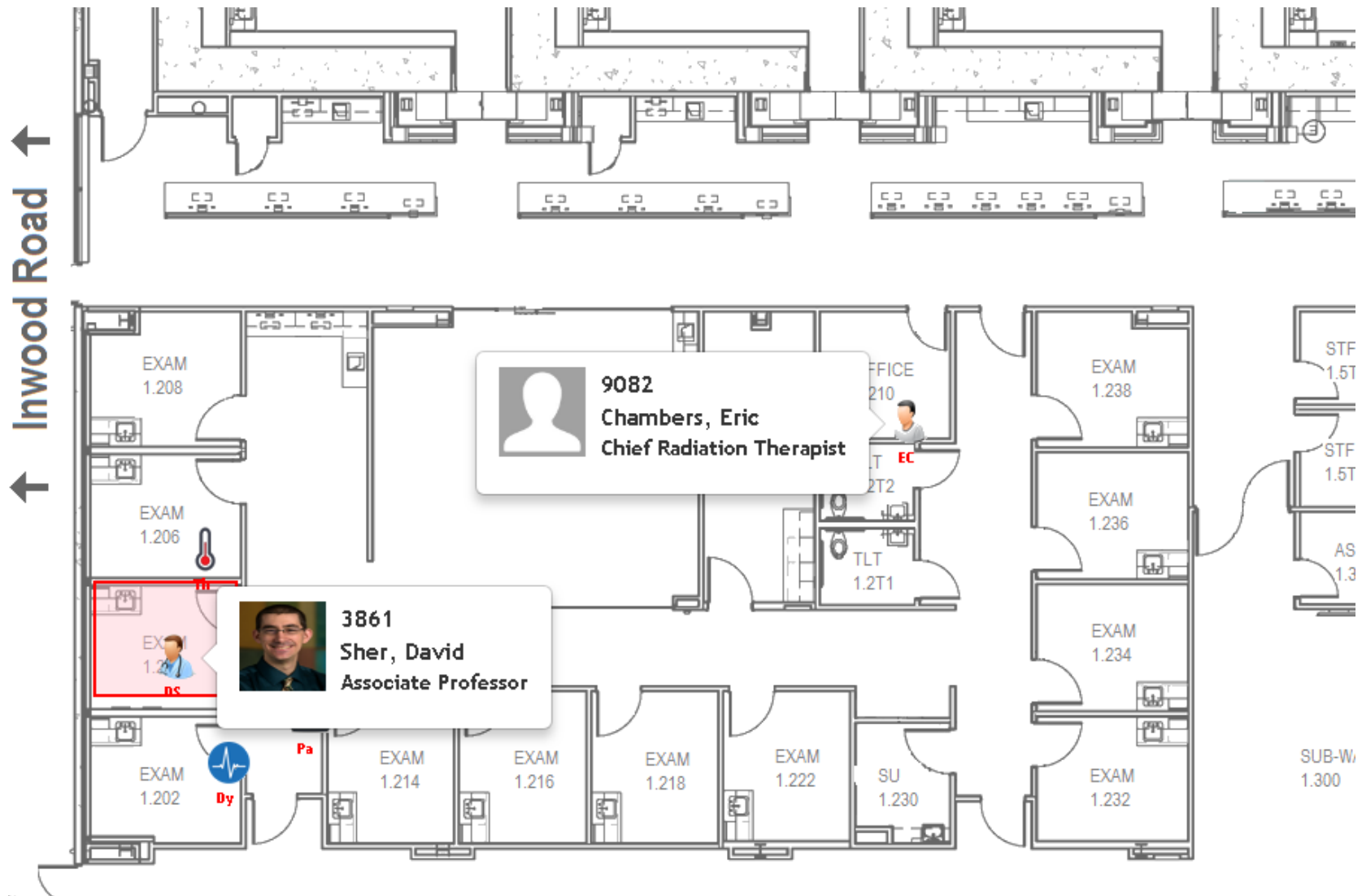
464 entries

TAG ID	SUBJECT ID	NAME	TYPE	Days	FREQ	Status	Delete Assoc	Battery Change	Dispose Tag	Location	Data Analytics
50479			Vac Lock	6	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50441			Mask	6	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50462			Vac Lock	7	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50442			Mask	7	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50451			Mask	7	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50444			Vac Lock	7	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50474			Bolus	9	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50458			Mask	9	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50450			Vac Lock	11	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics
50457			Vac	11	10	Active	Delete Association	Battery Changed	Dispose Tag		Data Analytics

Live Map app



Live Map app



Location “google”

david



DAVID

Mask

Location: TrueBeam 1 Back



Sher, David

david.sher@utsouthwestern.edu

Faculty

Last Seen: Teamwork Desimetry Monday, January 13, 2020 05:50:01 PM



DAVID K

Vac Lock

Location: Versa 2 Back



DAVID

Mask

Location: Versa 2 Back



, DAVID

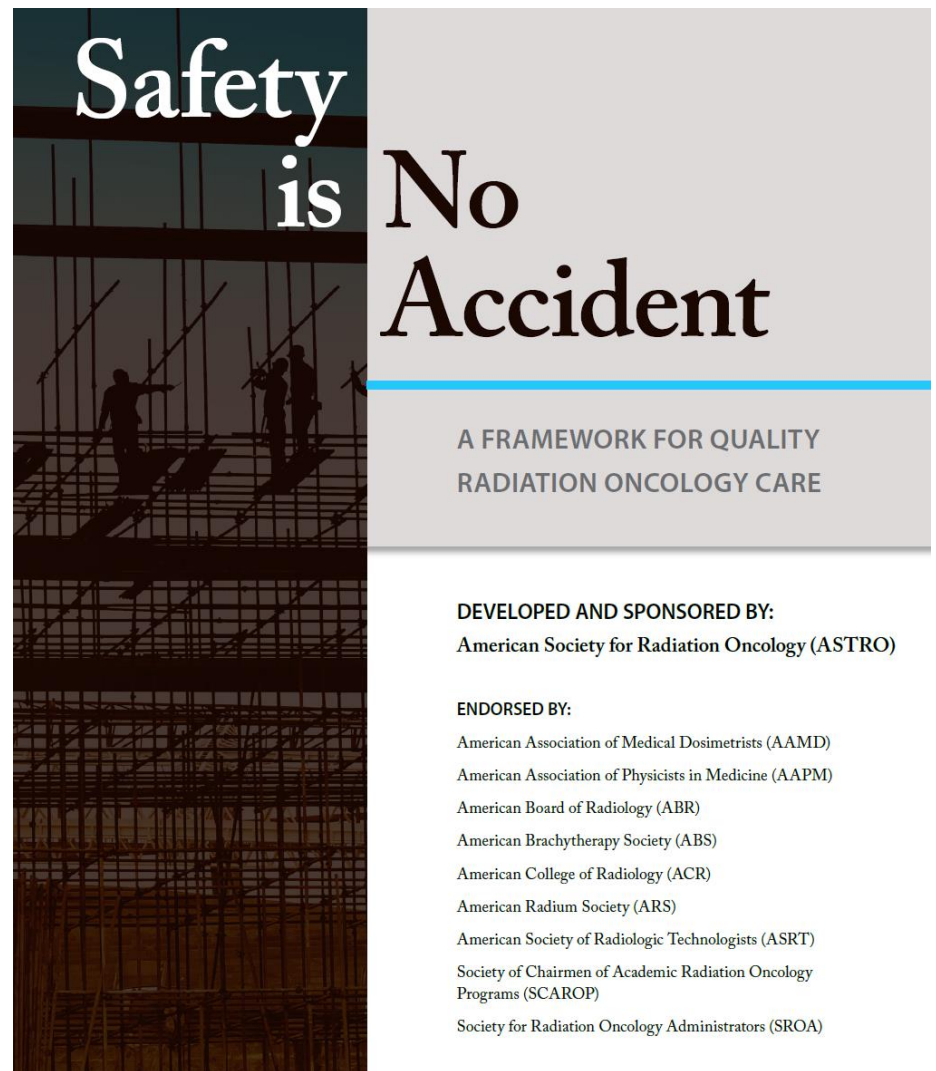
Vac Lock

Location: Versa 1 Back



RTLS assisted electronic checklist

One of the most effective strategies to improve safety of radiation therapy procedures is to use a checklist to verify all relevant items prior to each treatment delivery as suggested by the ASTRO committees.



Why use electronic checklist ?

1. Directly linked to treatment console.
2. Patient specific.
3. Can be automated by RTLS.
4. Web-based app that is easy to use and maintain.
5. Backed by a database to facilitate data analysis & investigation.
6. Paperless.

Electronic checklist – superset

UTSouthwestern

Medical Center

Tx LifeGuard

v1.1

TxLifeGuard Review

Tag Registration

Live Map

Logout

Ping MOSAIQ

21B

Change Machine

Last Checked: 2020-03-20 11:38:32

Patient Identification

NAME: BENEFIT ASSON

DOB: 01/19/1975

Not Checked

MRN: 740154

PHONE: 740154

N/A items

MD: BEN, BENEFIT

Not Ready

Site & Plan

Site: Brst R Init 4256 - 3D Conformal - 6X/18X Dose: 4256 cGy @ 266 cGy x 16

Fx #: 8 / 16

Checked

Fields: 1 - RT MED TANG, 2A - RT LAT TANG, 2B - RT LAT TANG 18x

Current SSDs: 88.9, 88.7, 88.7

Pattern: CT Sim;

Comment: 7 fx boost to follow

Immobilization

Setup Note: breastboard, incline 10, large@8, upper VB both arms up,D&F, head turned to left, stopper @1, knee C, long 8.0

Bite Block

Not Checked

N/A

Block

Not Checked

N/A

Body Frame

Not Checked

N/A

Bolus

Yes

No

N/A

Mask

Not Checked

N/A

Mold Care Cushion

Not Checked

N/A

Vac Lock

1

Not Checked

N/A

Setup & Motion Management

6 DOF

Not Checked

N/A

ABC

Not Checked

N/A

BladderFilling

Not Checked

N/A

Compression

Not Checked

N/A

Dental Trays

Not Checked

N/A

Dentures

Not Checked

N/A

Eyes Open

Not Checked

N/A

EyeShields/Drops

Not Checked

N/A

Magnet/Monitoring

Not Checked

N/A

No Swallow

Not Checked

N/A

NPO

Not Checked

N/A

Oral Contrast

Not Checked

N/A

Trach Out

Not Checked

N/A

VRT

Not Checked

N/A

Imaging Verification

Imaging Completed

Not Checked

None

N/A

Electronic checklist – patient-specific set

UTSouthwestern
Medical Center

Tx LifeGuard v1.1

TxLifeGuard Review

Tag Registration

Live Map

Logout

Ping MOSAIQ

VitalBeam1

Change Machine

Last Checked: 2020-03-20 11:39:53

Patient Identification

Checked

Male

N/A items

MD: [blurred]

Ready

Site & Plan

Site: Pelvis4500 - Arc IMRT - 10X Dose: 4500 cGy @ 180 cGy x 25
Fields: 1 - arc1 CCW, 2 - arc2 CW, 3 - arc3 CCW, 4 - arc4 CW
Pattern: IMRT, GU protocol

Fx #: 23 / 25

Checked

Current SSDs: 89.4, 89.4, 89.4, 89.4
Comment: Boost to follow (38 total tx)

Immobilization

Setup Note: FULL BLADDER F solid; hands on chest; lower vacbag at F2 LH= 10.4 tattoos

Vac Lock

1

Checked

N/A

Setup & Motion Management

BladderFilling

Checked

N/A

Imaging Verification

Imaging Completed

Checked

None

N/A

When the arrow button is clicked, the app will tell users where accessories are. So it is also an electronic finder.

Electronic checklist in action



Electronic checklist - analytics

<div> <div> UTSouthwestern Medical Center </div> <div> TxLifeGuard Review - Real Time Location System v1.1 </div> <div> Log out </div> </div>												
<input checked="" type="checkbox"/> Dates Between 03/17/2020 - 03/24/2020 Search by: MRN Patient MRN Search Download Patients Statistics												
	21A	21B	21C	Agility	Cyberknife	TrueBeam1	TrueBeam2	Versa1	Versa2	VitalBeam1	VitalBeam2	Total
Percentage	81.5 %	92.5 %		95.8 %	98.3 %	78.6 %	90.6 %	91.7 %	94.6 %	85.5 %	96.5 %	89.7 %
# record	88	86	0	68	57	99	125	111	87	130	137	988
# treatment	108	93	0	71	58	126	138	121	92	152	142	1101
# detect	0	0	0	0	58	87	127	117	83	134	130	736
# miss	0	0	0	0	0	3	2	0	2	3	9	19
# wrong	0	0	0	0	0	4	11	0	4	6	4	29
Unlogged treatments												
Index	MRN	Full name						Date		Machine		
1								03/17/2020		21A		
2								03/17/2020		21A		
3								03/18/2020		21A		
4								03/19/2020		21A		
5								03/19/2020		21A		
6								03/20/2020		21A		
7								03/23/2020		21A		
8								03/23/2020		21A		
9								03/23/2020		21A		
10								03/23/2020		21A		
11								03/24/2020		21A		

Result of using electronic checklist

The RTLS assisted electronic checklist works well in clinic. Due to automation and minimalistic design, the minor extra work for the care team is rewarded with noticeable improvements on clinical practice. When the care team is getting used to the electronic checklist, it will become even more effective.

	1 year no Lifeguard	4 months with Lifeguard	Projected one year with Lifeguard
Event total	16	4	12
Near miss total	12	3	9
Combined	28	7	21

Timeboard – another RTLS app

UTSouthwestern Medical Center		Monday, 1/13/2020, 9:52a		TrueBeam1
Initial	Appointment	Arrival (wait min)	Activity	
JB	9:20a	9:15a (36)	IMRT Complex	
TP	10:00a	9:38a (14)	IMRT Complex	
NM	10:20a	9:47a (4)	IMRT Complex	

1. Have patients well informed
2. Talk to patients when they had waited for too long
3. Do adaptive scheduling when able
4. A reminder for care team

Attendance auto check-in

Attendance - Real Time Location System v1.1

12/02/2020

-

03/18/2020

Type

All

Profession

All

Threshold

50%

Q Search

Download

</

- Chart rounds
- Seminars
- Lectures
- Oral exams

Potential applications

- **Upon patient's arrival**
 - Patient auto check-in
 - Kiosk / greeting board
 - Appointment reminder/updates to smart phone
- More analytics tools to improve clinical workflow and experience
- ...

Automated communications

1. Patient notification

- a. Text to patient's phone (reminder or updates)
- b. Smart bulletin board (machine status)

2. Notification within a care team

- a. Interactive phone book
 - 1) Email
 - 2) Pager
 - 3) Call
- b. Automated reminder in email/pager
 - 1) Clinical duty next day
 - 2) Tasks to fulfil
 - 3) Unfinished work before overdue

3. Interactive PADs

Patient notification

- An automated SMS text messaging program is used to deliver daily appointment time reminders to patients on an elective basis. Automated text messages are sent 2 hours before treatment appointments with appointment-specific information.

(Jun Tan, et. al., "Automated Text Message Reminders Improve Radiation Therapy Compliance," IJOBP, Vol. 103, No. 5, pp. 1045e1052, 2019. DOI: <https://doi.org/10.1016/j.ijrobp.2018.11.050>)

Results of patient notification

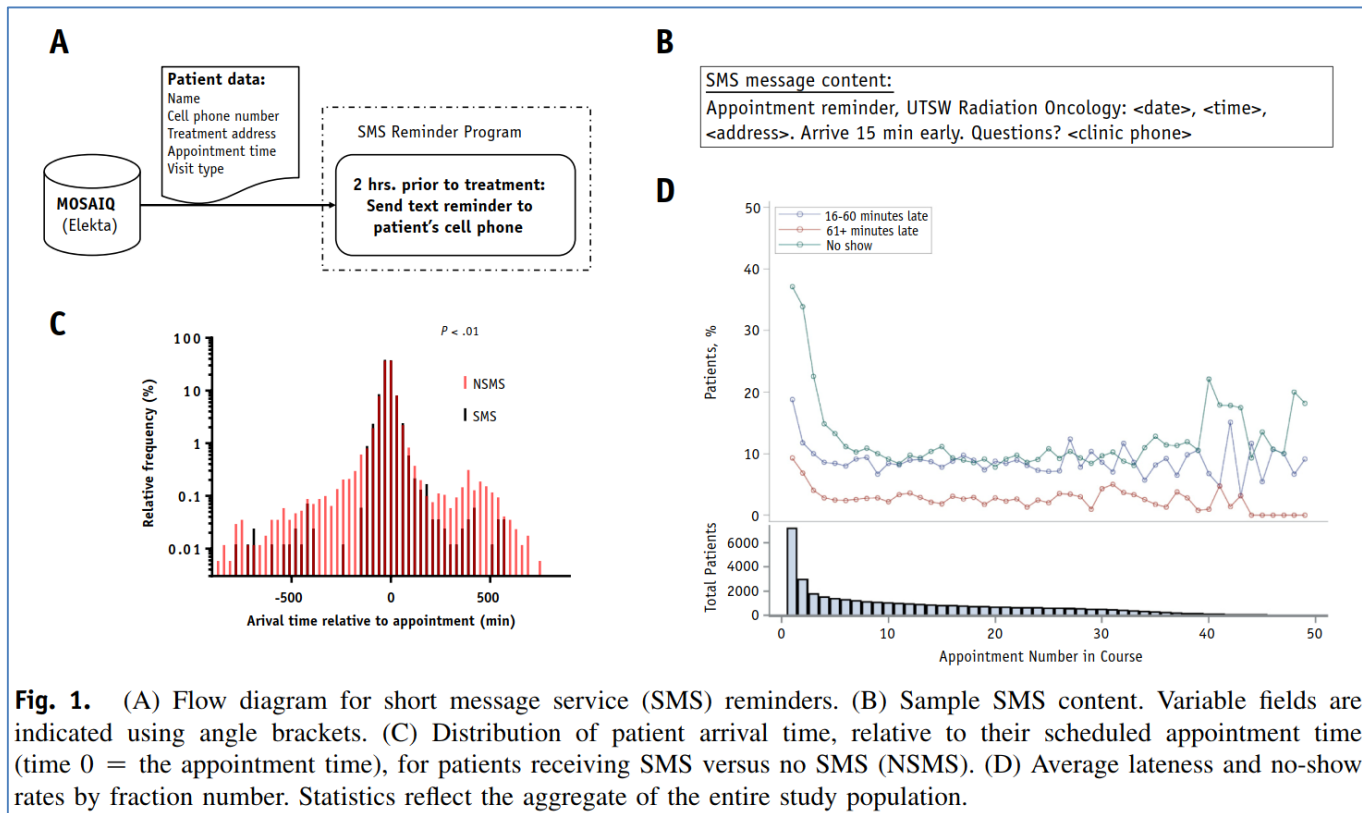


Fig. 1. (A) Flow diagram for short message service (SMS) reminders. (B) Sample SMS content. Variable fields are indicated using angle brackets. (C) Distribution of patient arrival time, relative to their scheduled appointment time (time 0 = the appointment time), for patients receiving SMS versus no SMS (NSMS). (D) Average lateness and no-show rates by fraction number. Statistics reflect the aggregate of the entire study population.

Machine status bulletin board

- Whether the treatments on each machine have been on schedule.
- The physicians seeing the patients.
- The machine doctor.

Machine status bulletin board

5:27:03 PM

Machine Status

1	On time
2	35 min behind
3	On time
4	On time
5	more than 60 min behind
6	25 min behind
7	On time

Weekly MD Visits*



*Physicians shown above are seeing their patients who are on treatment today

Interactive searchable phonebook

[RO Board](#) |
 [Contact](#) |
 [+Clinic](#) |
 [Physics](#) |
 [MRB](#) |
 [Staff](#) |
 [DOT](#) |
 [Groups](#) |
 [Clinical Operations Recommendation Sheet](#) |
 [Admin](#)

[Search](#)

Notice! Please allow popups, otherwise pager messages will not send.
See an error? Please let your division admin know about updates.

On Call / Group Pagers	Ext.	Phone	Pager	Fax	Location
MD (group)			97-23		
Resident (group)			97-28		
MROC IT (on call) - Click for Help Request			21-03		
Supervisor (group)			97-50		
Dosimetry POD A (CNS, HN, PED)			21-33		
Dosimetry POD B (Breast, Lung, GYN)			21-35		
Dosimetry POD C (GU, GI)			21-37		
Physics Residents (group)			97-78		
Physician	Ext.	Wi-Fi	CureATR/AM	Title	Office
A...			395	Assistant Professor	EC2.244
A...			115	Professor	EC2.312
A...			205	Assistant Professor	EC2.228
A...			221	Assistant Professor	EC2.210
C...			206	Professor and Chairman	EC3.160D
D...			202	Assistant Professor	EC2.218
D...			890	Assistant Professor	EC2.350
F...			931	Assistant Professor & Residency Program Director	EC2.346
G...			026	Assistant Professor	EC2.240
H...			905	Associate Professor	EC2.342
I...			153	Assistant Professor & Director of Clinical Research	EC2.334
J...			176	Assistant Professor	EC2.206
K...			137	Associate Professor	EC2.328
K...			249	Assistant Professor	EC2.234

Interactive Pads for exam rooms

- Every exam room has a tablet outside the room by the door.
- Patient in exam room, check-in and – out time.
- Staff members in room, check-in and – out time.
- Paging a staff by clicking a function button.
- Holding room for

Room 5
EROC

OTV

MD: [Redacted]
Res: [Redacted]
RN: [Redacted]

UT Southwestern
Medical Center

Action

RN ²	RN Done
Page RES/APP	RES/APP Inside
Page MD	MD Inside
	Checkout

43 min
5:42:44 PM

Automated chart rounds

- A list of patients sorted by disease group and physicians.
- Plan documents can be downloaded and reviewed
- Enter review comments.
- Log treatment break cause.
- Generate attendance report.

Chart rounds, patient list and review

RO Board | Chart Round | To log attendance, use "bit.ly/roattend" | Log out

Ph | Patient Name

Iye | [Name]
Iye | [Name]
Iye | [Name]
Jia | [Name]
Jia | [Name]
Kir | [Name]
Kir | [Name]
Ku | [Name]
Ku | [Name]
Ku | [Name]
Mc | [Name]
Nv | [Name]
Ra | [Name]
Ra | [Name]
Ra | [Name]
Ra | [Name]
Ra | [Name]
Sa | [Name]
Sa | [Name]
Sa | [Name]
Sa | [Name]

Diagnosis C30.1* Malignant neoplasm of middle ear;

Prescription Start Date: 03/23/2020

Site	Dose (cGy)	FX	Technique	Treatment Intent	Tx_Plan
HNSIB7000Re	1000	5	Arc IMRT	Definitive	Download
HN SIB 7000	6000	30	Arc IMRT	Definitive	Download

To-Do

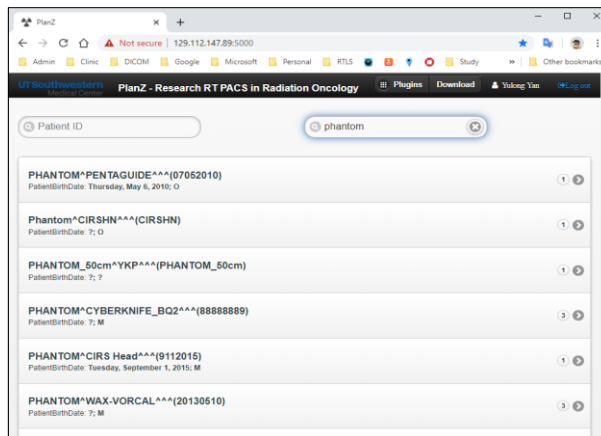
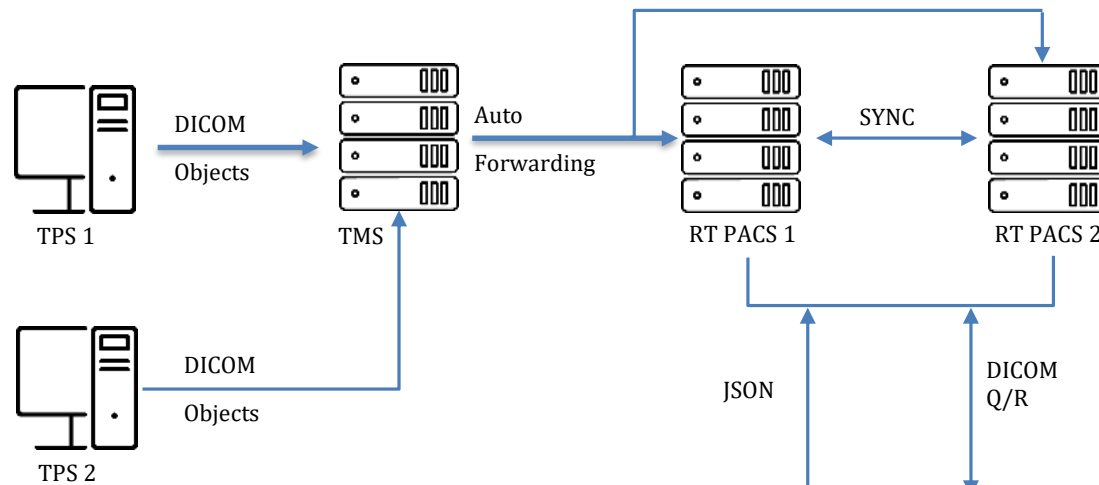
Last Reviewed

Case Reviewed

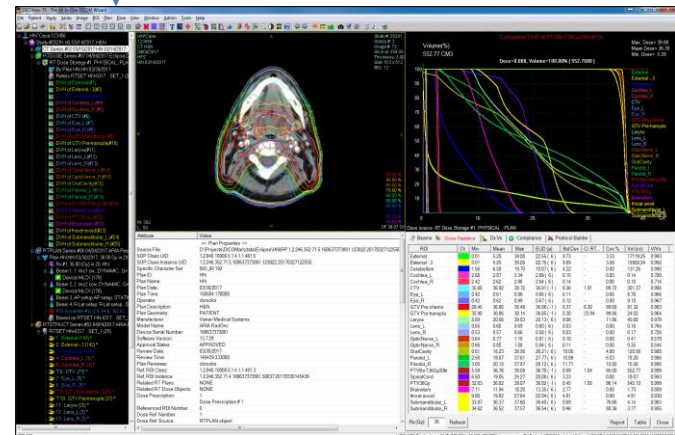
Automated plan archiving - DICOM

- DICOM stands for Digital Imaging and Communication in Medicine.
- It is the standard devised by the National Electrical Manufacturers Association (NEMA) in association with American College of Radiology (ACR), aiming to facilitate interoperability between systems claiming DICOM conformance in a multi-vendor environment.
- DICOM modalities for radiation therapy are also called DICOM RT. A RT plan can be exported and archived in a Picture Archiving and Communication System (PACS).
- A PACS equipped with a RT viewer is called RT PACS.

Automated plan archiving



Web portal



RT Viewer

Why do we need a RT PACS ?

- A secondary plan backup system in addition to vendor provided backup solutions.
- Standardized data format, is vendor independent.
- Interchangeable between different systems.
- Fast data retrieval for clinical practice and research.
- Much longer “shelf life”.

In short, things are easier in DICOM.

SAM Questions

Question 1

What is RTLS ?

- A. A Real-Time Location System that tracks assets and people for a better workflow.
- B. A Radiation Therapy Localization System that localizes and tracks tumor in real time.
- C. A Real-Time Localization System that localizes and tracks moving targets.
- D. A Radiation Therapy Lifeguard System to improve patient's safety in a radiation therapy clinic.

Question 2

Ways to improve safety of radiation therapy procedures.

- A. Check patient's identity in at least two methods.
- B. Match treatment plan and its treating site.
- C. Use a patient-specific checklist to verify the completion of all checks.
- D. All of above.

Question 3

Better communications within a care team, and between patients and care team will

- A. increase clinical operation cost and interrupt clinical procedures too often.
- B. improve clinical operation efficiency and patient experience.
- C. improve patient safety.
- D. only decrease patients' wait time.

Question 4

Can radiation therapy plans be archived in DICOM objects ?

- A. No, radiation therapy plans cannot be archived in DICOM format.
- B. Yes.