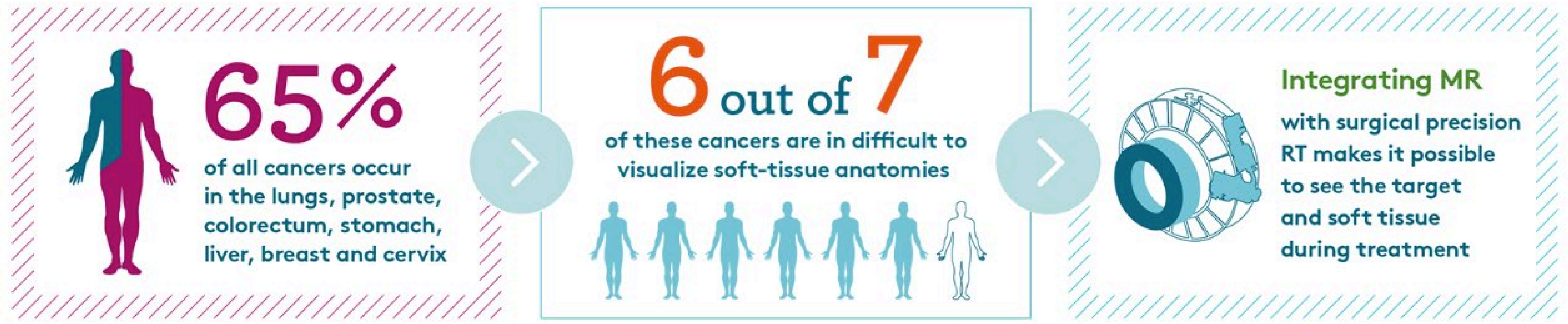
DCA

Elekta

What is Elekta Unity?


65%
of all cancers occur
in the lungs, prostate,
colorectum, stomach,
liver, breast and cervix
6 out of 7
of these cancers are in difficult to
visualize soft-tissue anatomies
Integrating MR
with surgical precision
RT makes it possible
to see the target
and soft tissue
during treatment


Elekta MR-linac
Consortium collaboration
ESTABLISHED
2012
Unites
>15
pioneering sites around the world to provide evidence based introduction of MR/RT with established protocols.
200
scientists
Founded by
7
world-leading cancer centers
more than 120
peer-reviewed scientific papers
12
RESEARCH DEVICES OPERATIONAL

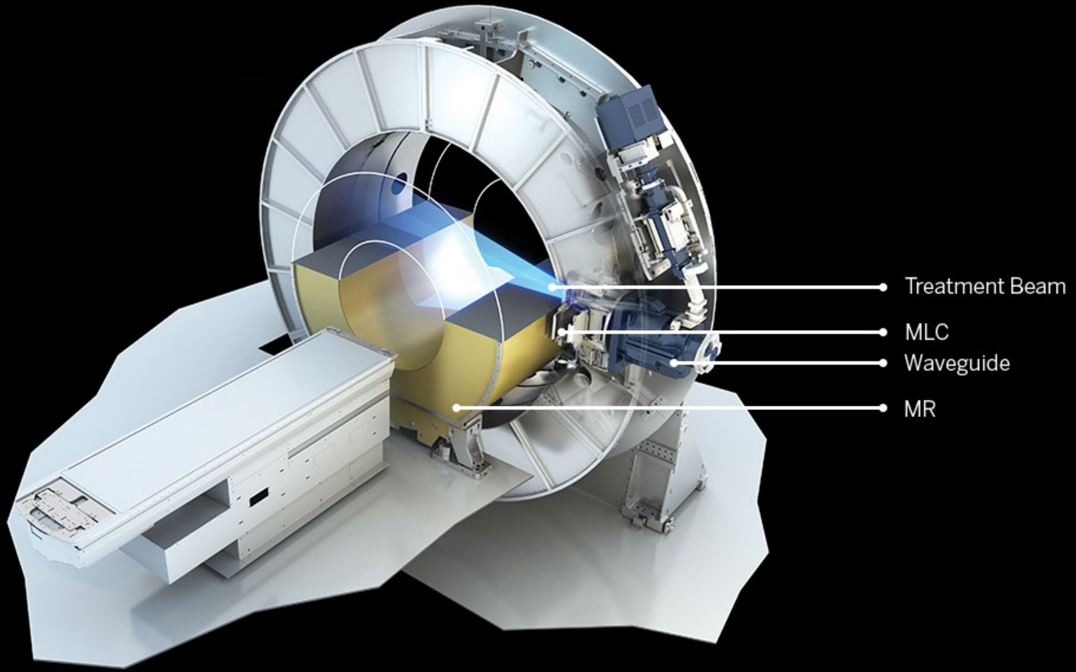
NEXT GENERATION LINAC
With state-of-the-art, 160-leaf MLC

1.5T HIGH-FIELD MR IMAGING
For crystal clear target visualization

SLIP RING TECHNOLOGY
Up to 6x faster gantry rotation for continuous treatment at any angle

INTELLIGENT SOFTWARE
Integrated workflow for unprecedented personalization

SHORT, WIDE BORE MAGNET
70 cm width bore for patient comfort



Elekta MR-linac is a work in progress and not available for sale.

Elekta MR-linac is a work in progress and not available for sale.

Image credit: The Royal Marsden

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Health

'More cures, fewer side-effects' with pioneering radiotherapy machine

Fergus Walsh
Medical correspondent
@BBCFergusWalsh

24 September 2018

Share

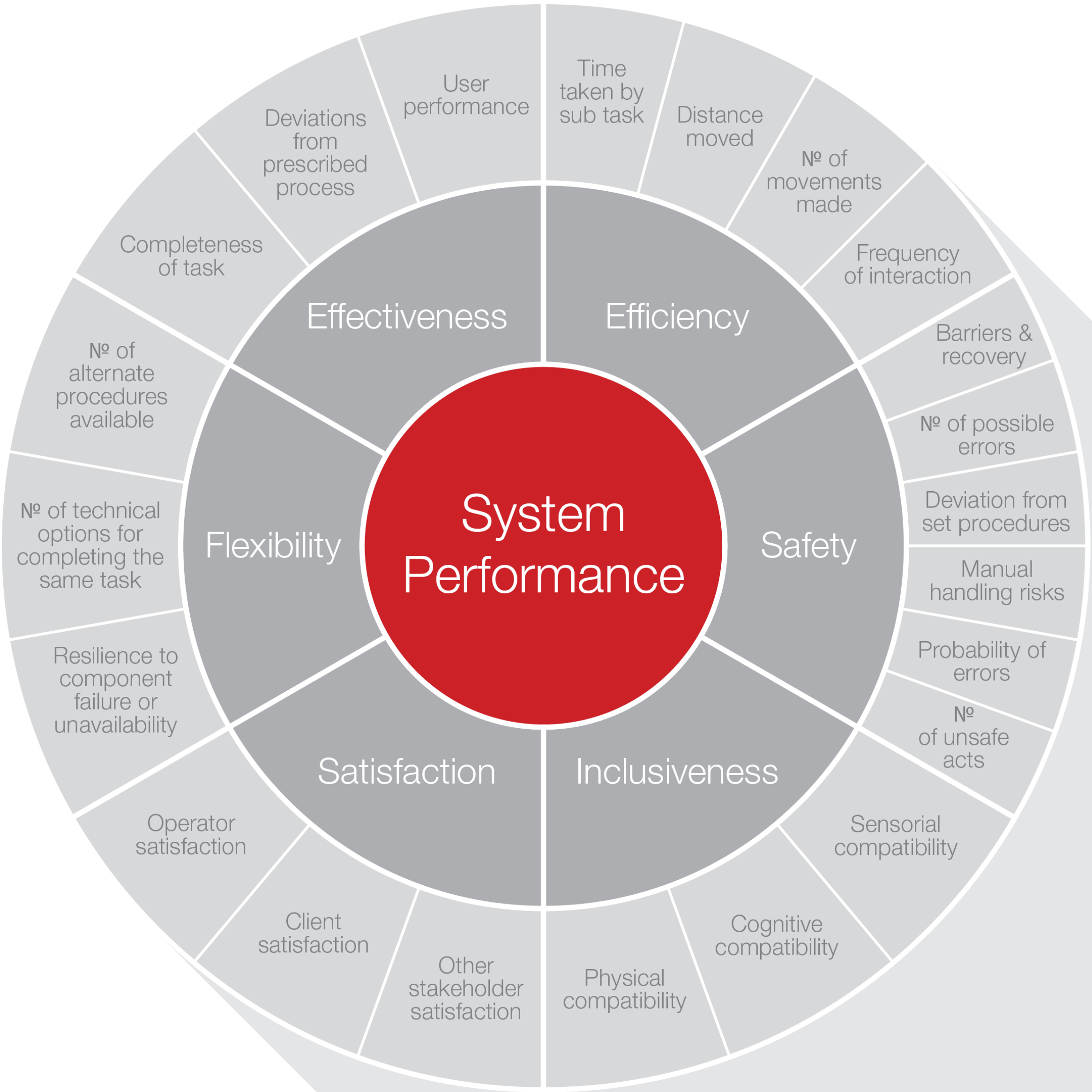
Barry Dolling is prepared for treatment in the MR Linac by therapeutic radiographers

The first patient in the UK has been treated with a pioneering new radiotherapy machine.

The MR Linac simultaneously scans tumours inside the body while delivering X-ray radiation beams.

Creating a vision

Evidence-based design



The first stage of the analysis was to define metrics of system performance.

At the highest level, the functional purpose of the system is twofold, firstly to improve patients quality of life but also to return on investment. The relative balance placed on these changed by market.

The measure of performance included efficiency, safety, inclusiveness, satisfaction, flexibility and effectiveness.

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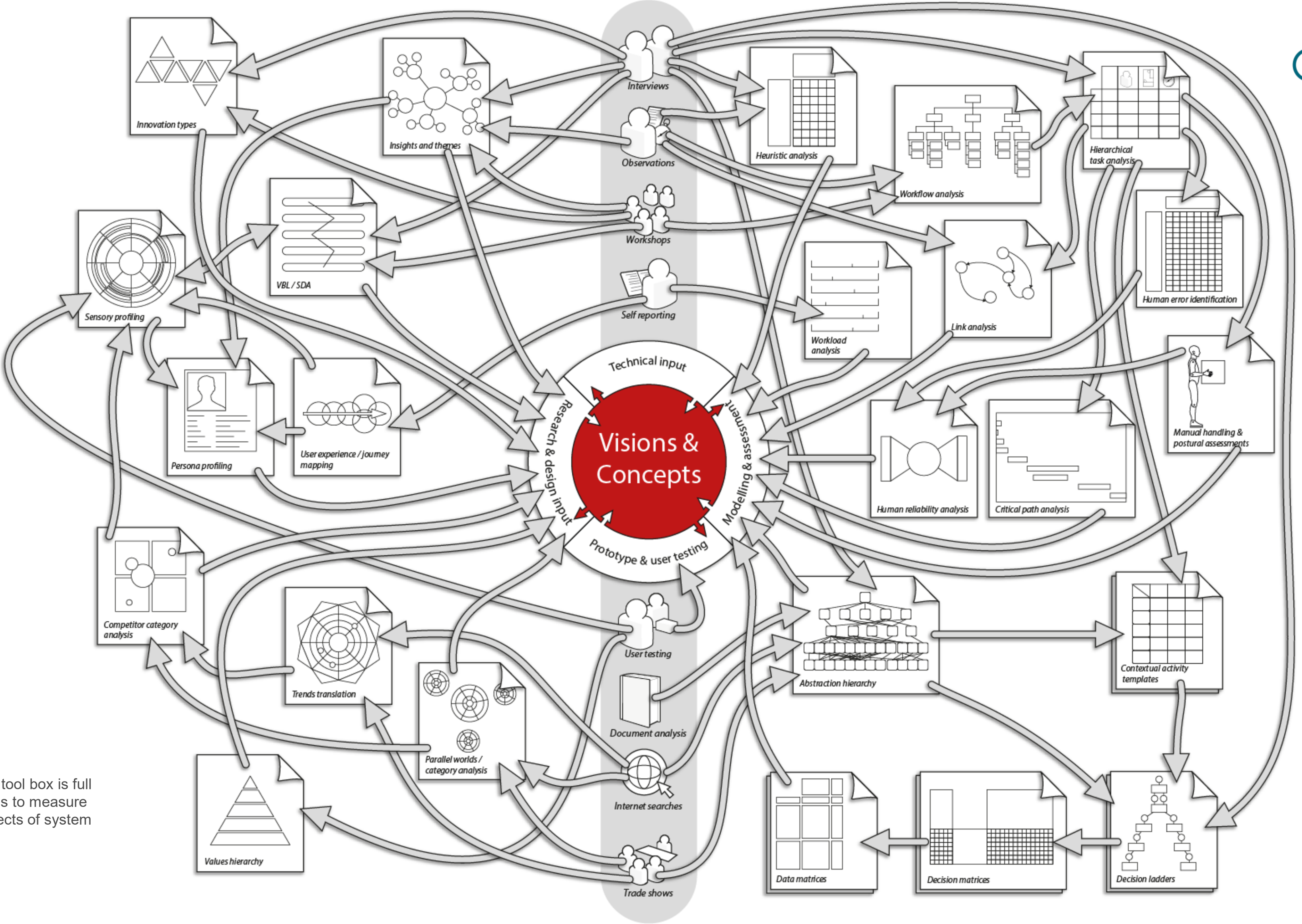
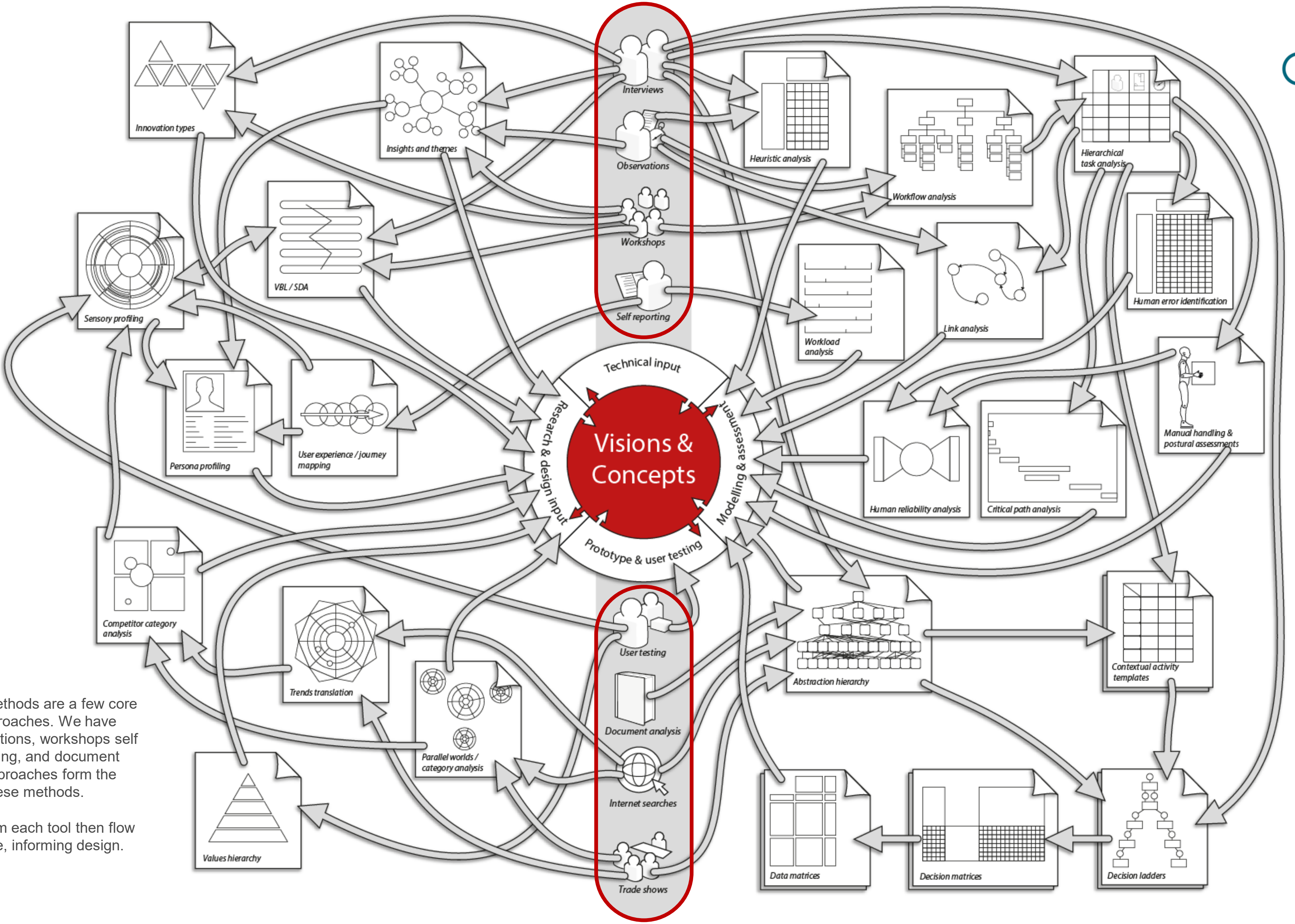


The human factors tool box is full of tools that allow us to measure these different aspects of system performance.



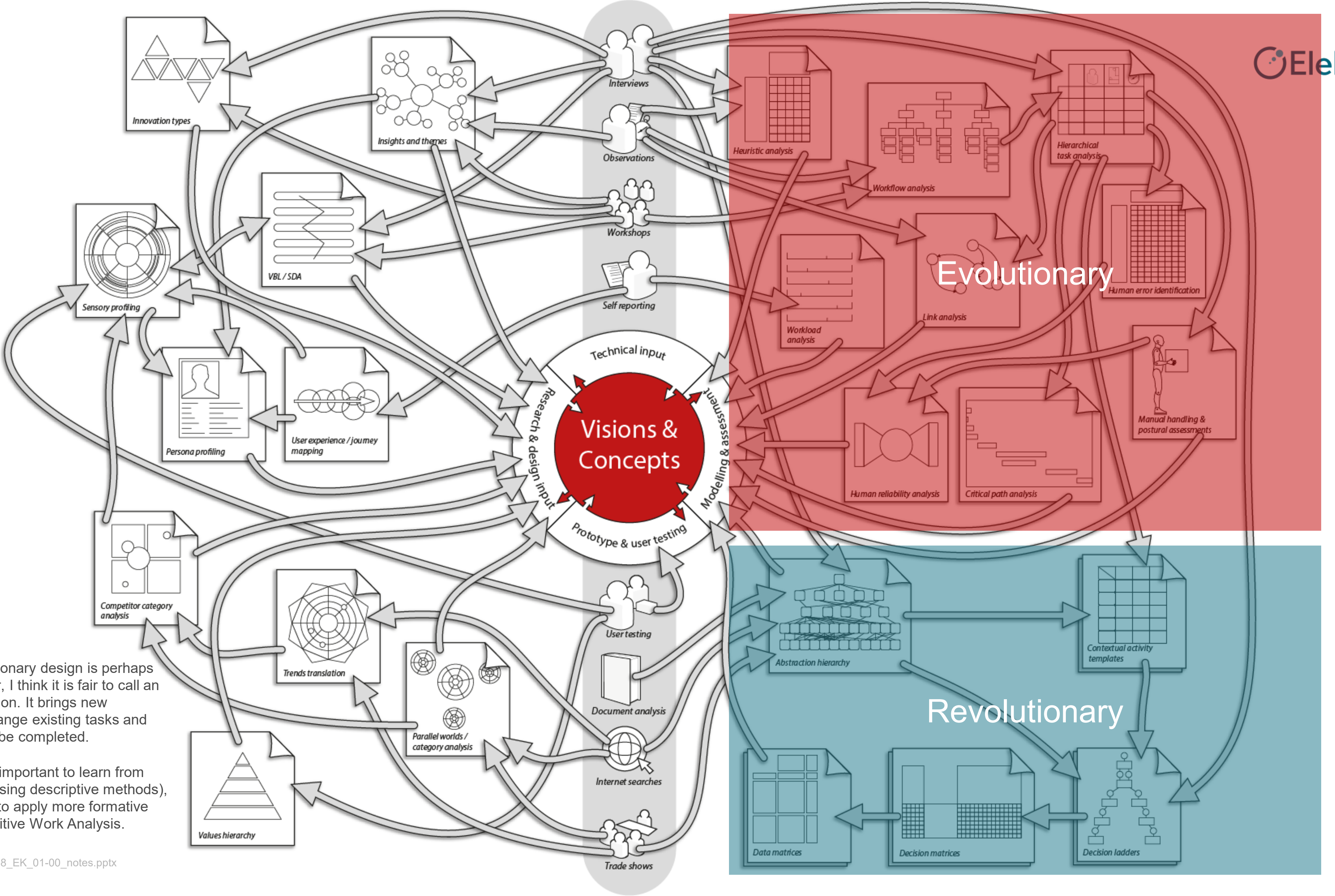
Central to these methods are a few core data collection approaches. We have interviews, observations, workshops self reporting, user testing, and document analysis. These approaches form the back-bone of all these methods.

Insights gained from each tool then flow back into the centre, informing design.

Thus, the goals is to develop designs that are:

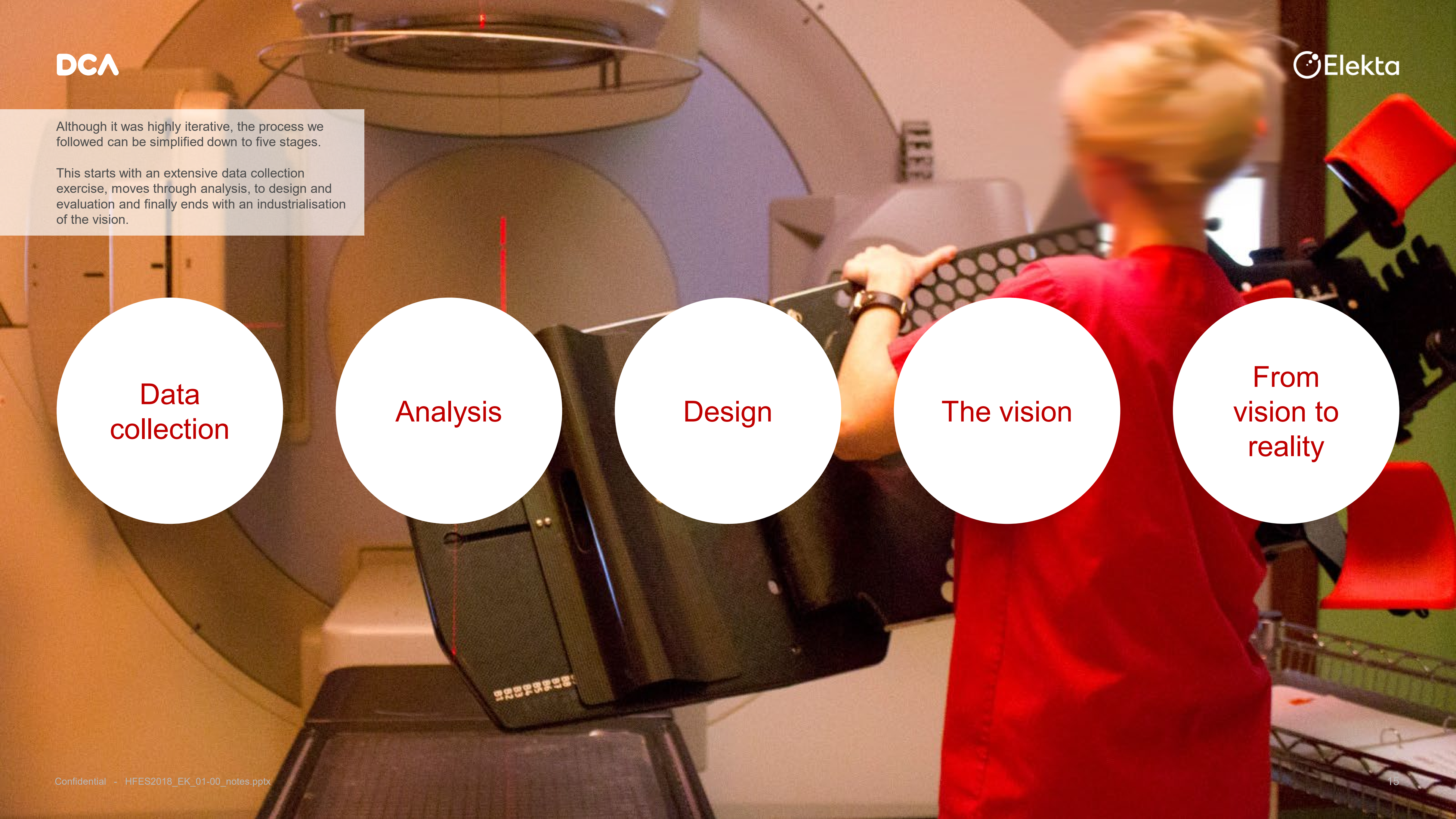
Inspired by
Informed by
Evaluated against

An evidence base from Human Factors methods



The phrase revolutionary design is perhaps overused. However, I think it is fair to call an MR-Linac a revolution. It brings new capabilities that change existing tasks and allow new tasks to be completed.

As such, while it is important to learn from existing systems (using descriptive methods), it is also important to apply more formative tools such as Cognitive Work Analysis.



Although it was highly iterative, the process we followed can be simplified down to five stages.

This starts with an extensive data collection exercise, moves through analysis, to design and evaluation and finally ends with an industrialisation of the vision.

Data collection

Analysis

Design

The vision

From vision to reality

Data collection

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DCA worked with Elekta on this project between 2010 and 2012 creating an evidence-base built from:

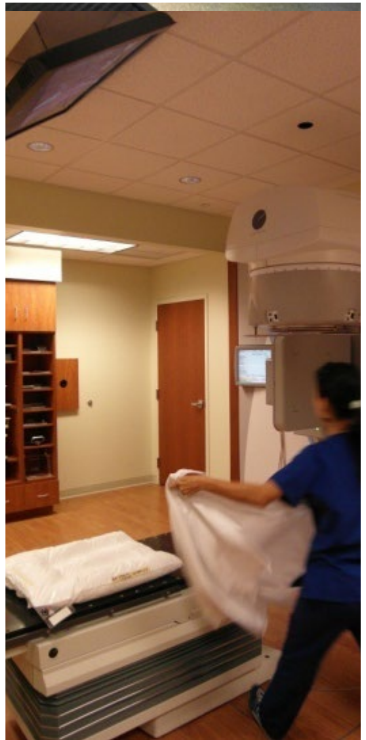
- 7 treatment sites visited worldwide
- Over 90 hours of observation at treatment centres (~360 treatment sessions)
- 30 interviews with healthcare professionals worldwide (fieldwork and phone interviews)
- 23 interviews with Elekta internal stakeholders from business, clinical specialists, technical, complaints, training, safety, regulatory and marketing
- 2 tradeshow visits

Ethnography

Observing approximately 360 treatments across seven treatments sights.

After-hours interviews and walkthroughs.

Two researchers following the workflow in the treatment room and the control room.



Because of the radiation, much of the workflow must be delivered from a separate control room.

This is a typical control room set up with two radiotherapists, one leading the treatment and the second in a checking role, they alternated this for each treatment.

Attention must be divided between CCTV footage of the patient and displays communicating the equipment and treatment status.

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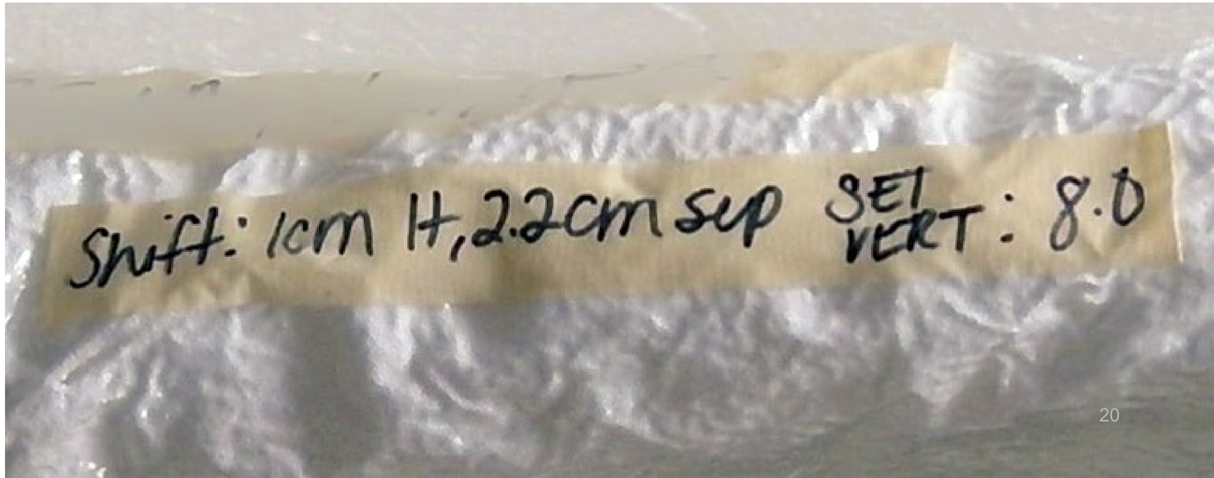
Latent needs

Even before processing any of the data, we were able to observe a range of latent needs within the system

Faster throughput was a key theme in some locations, notably Brazil, where there were long waiting lists to gain access to radiotherapy machines. We learnt a lot from the current efficiency saving processes that had been adopted at different sites.

Access to information was also a key theme. Information about the patients setup was often recorded on their unique support aids.

This showed a very clear latent need for greater information at the point of use.



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Analysis

Hierarchical task analysis (HTA)

Identify the patient and relate them to the schedule
4.1 Patient registration

4.2 Manage patient
Explain the treatment process

Set up the machine to receive the patient, add setup aids
4.3 Machine preparation

4.4 Patient loading
Sit the patient on PSS and lay them down

Configure setup aids, position the patient
4.5 Patient set up

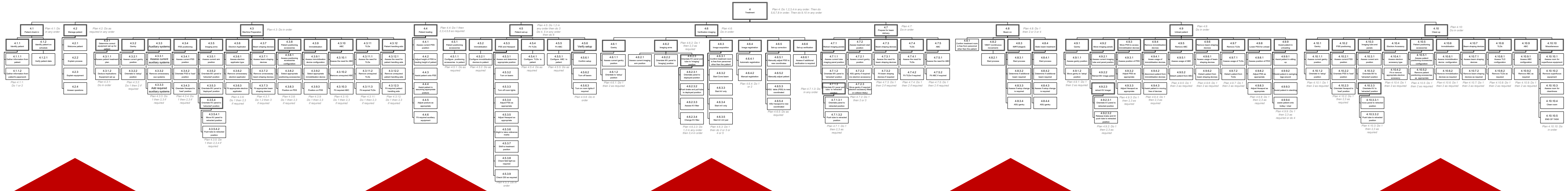
4.6 Verification imaging
Image the patient (if required)

Adjust the position of the patient, retract panels (if required)
4.7 Prepare for beam

4.8 Beam on
Treat patient

Remove immobilisation devises, help patient
4.9 Unload patient

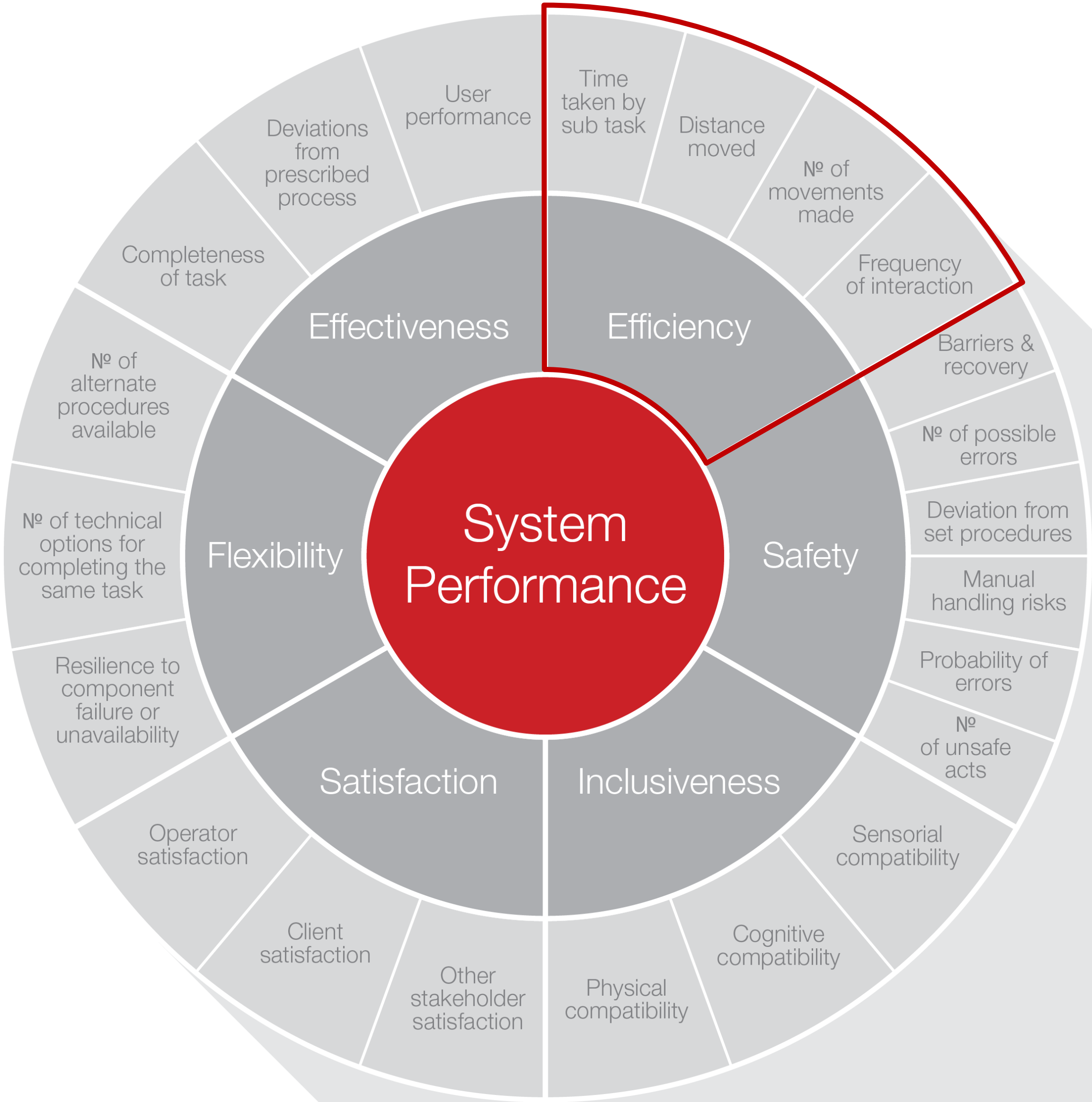
4.10 Clean up
Wipe down machine, reset ready for next patient



The cornerstone of the analysis of the current system was an HTA. The treatment process is largely linear and decomposes well into task steps.

There are 10 high level sub-tasks in the process that were found to be uniformly followed.

Variation between sites tended to occur at the base level operation level.


System Performance
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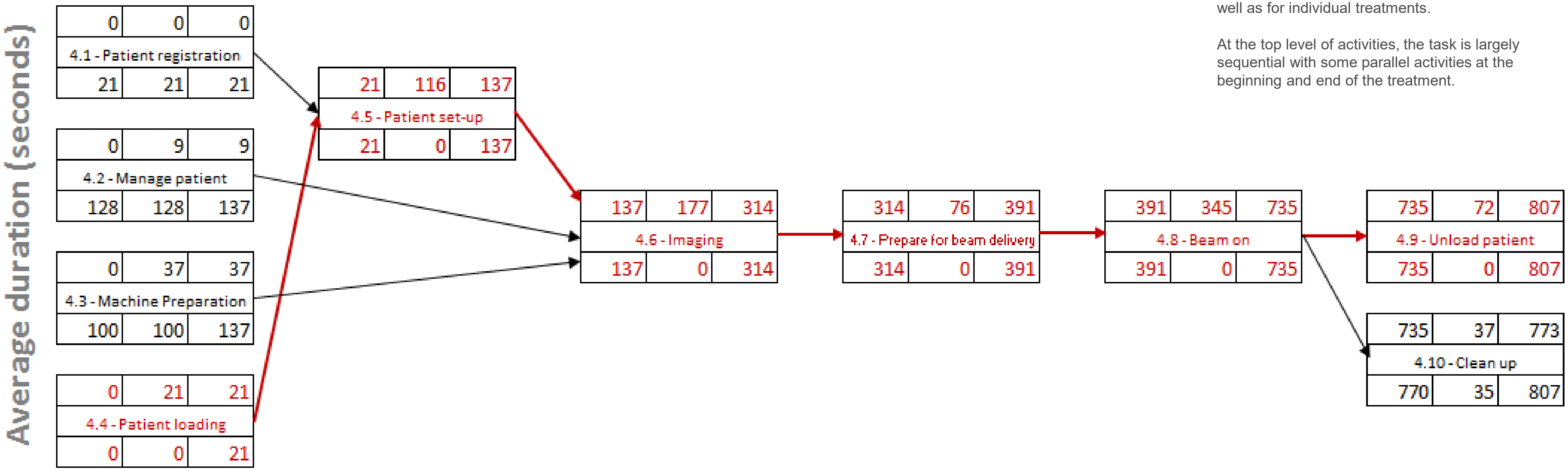
№ of alternate procedures available
Completeness of task
Deviations from prescribed process
User performance

Critical path analysis (PERT charts)

This chart shows average task completion times broken down by stages (as described in the HTA)



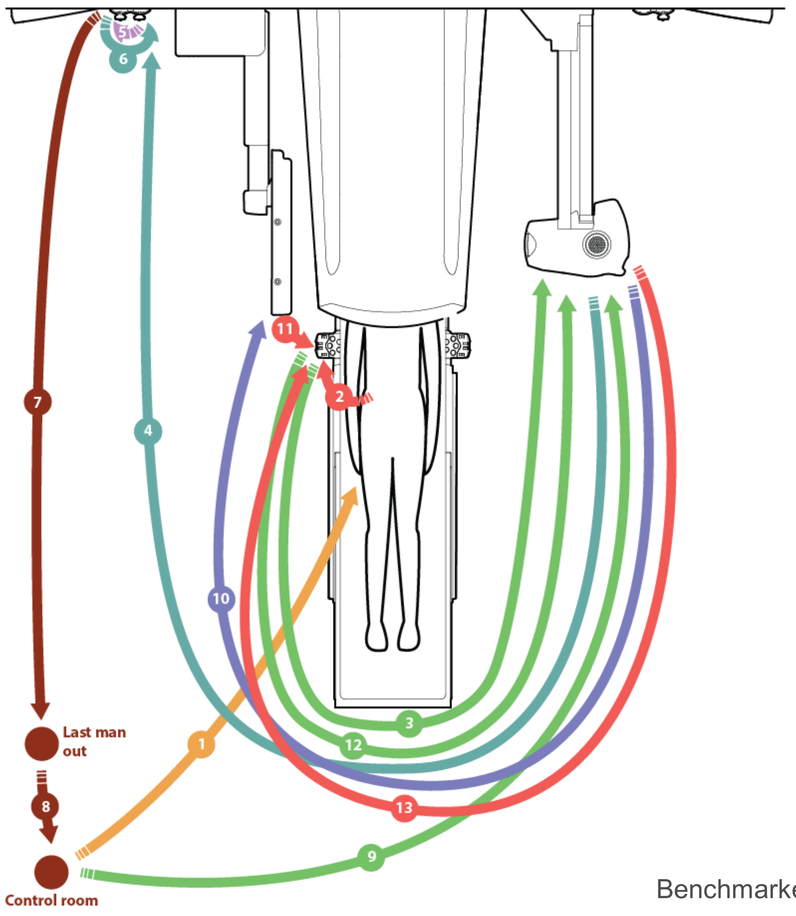
Data from the HTA could be explored in PERT (Program Evaluation Review Technique) charts to identify the critical path.

Understanding this critical path is an important step in reducing treatment times.

These were completed based on site averages as well as for individual treatments.

At the top level of activities, the task is largely sequential with some parallel activities at the beginning and end of the treatment.

Link analysis



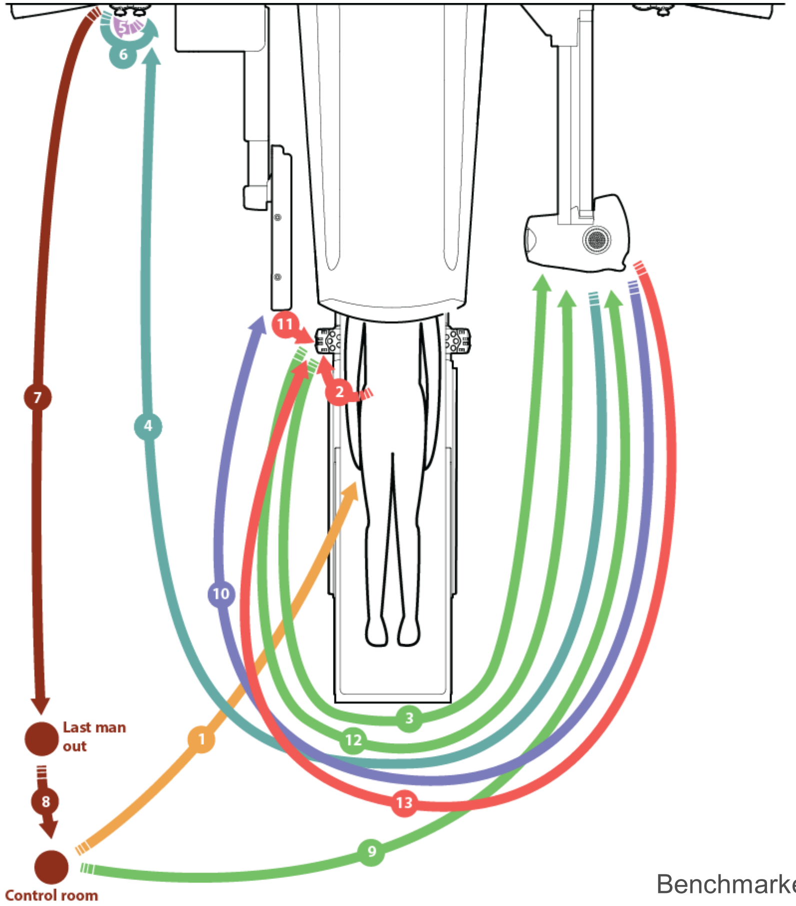
Benchmarked system

Likewise, we expanded on the HTA using Link analysis diagrams.

This diagram shows a link analysis model for a typical treatment setup.

Each of the numbered arrows indicated a movement made by the radiotherapist. A total of 13 moves are required in a typical treatment. Much of this stems from a requirement to manually interact with elements of the machine (e.g. deploy and retract imaging panels), or move to control locations.

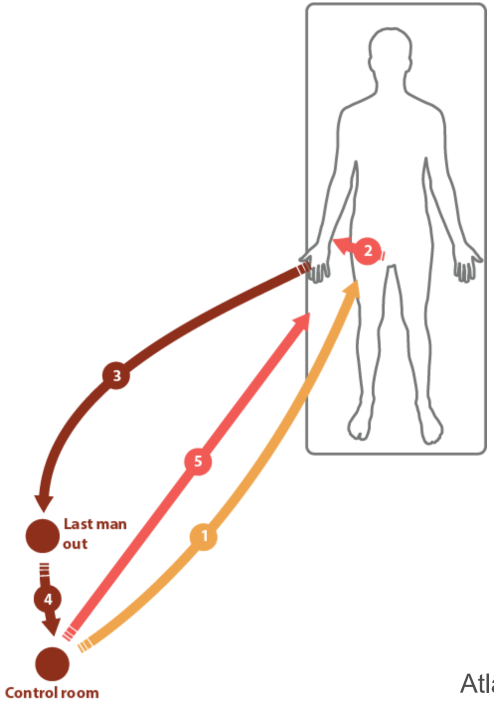
Link analysis



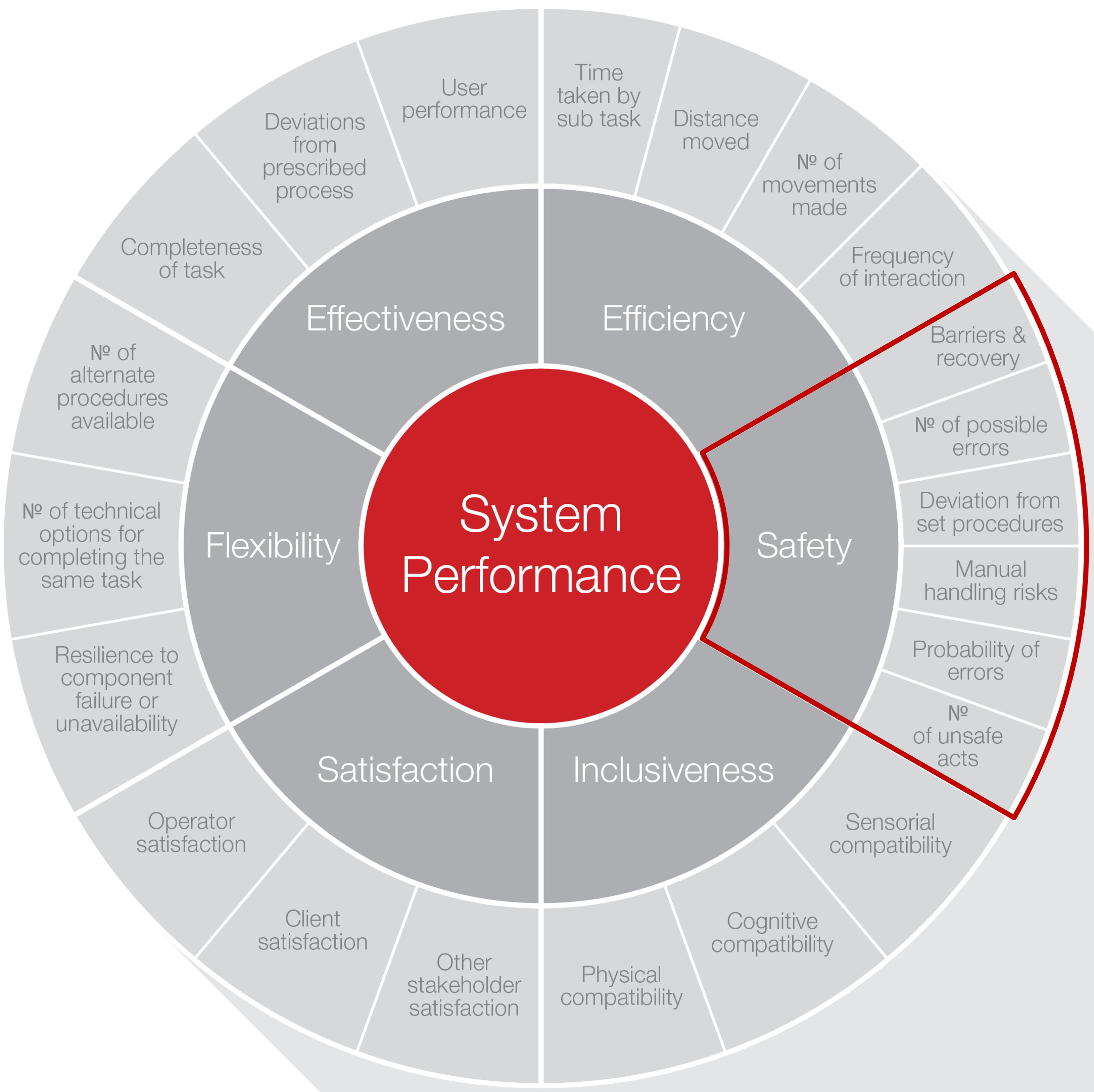
Benchmarked system

The diagram on the right shows how this has been simplified for the Atlantic vision, for the same task we were able to reduce the number of movements from 13 to 5.

Much of this has been achieved by bringing the controls to the point of use, reducing the need to move around the treatment room.



Atlantic vision



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Deviations from prescribed process

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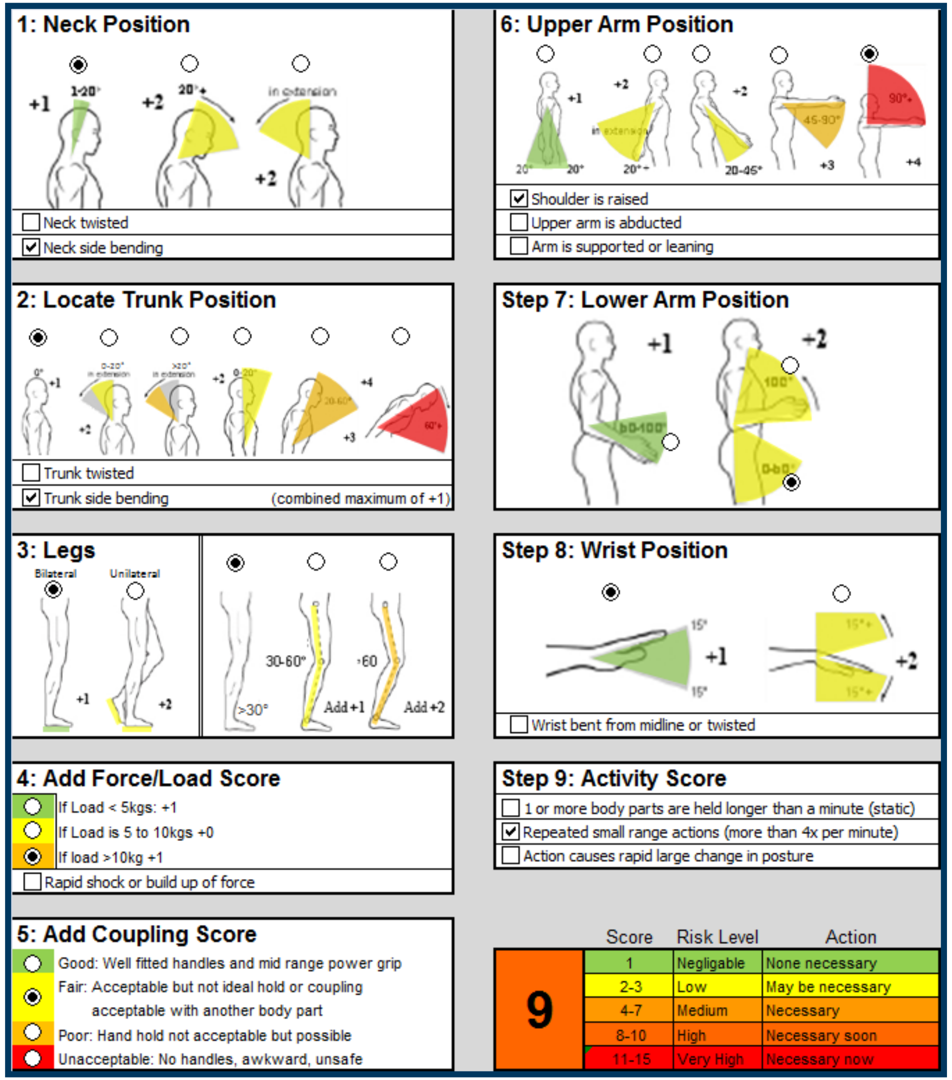

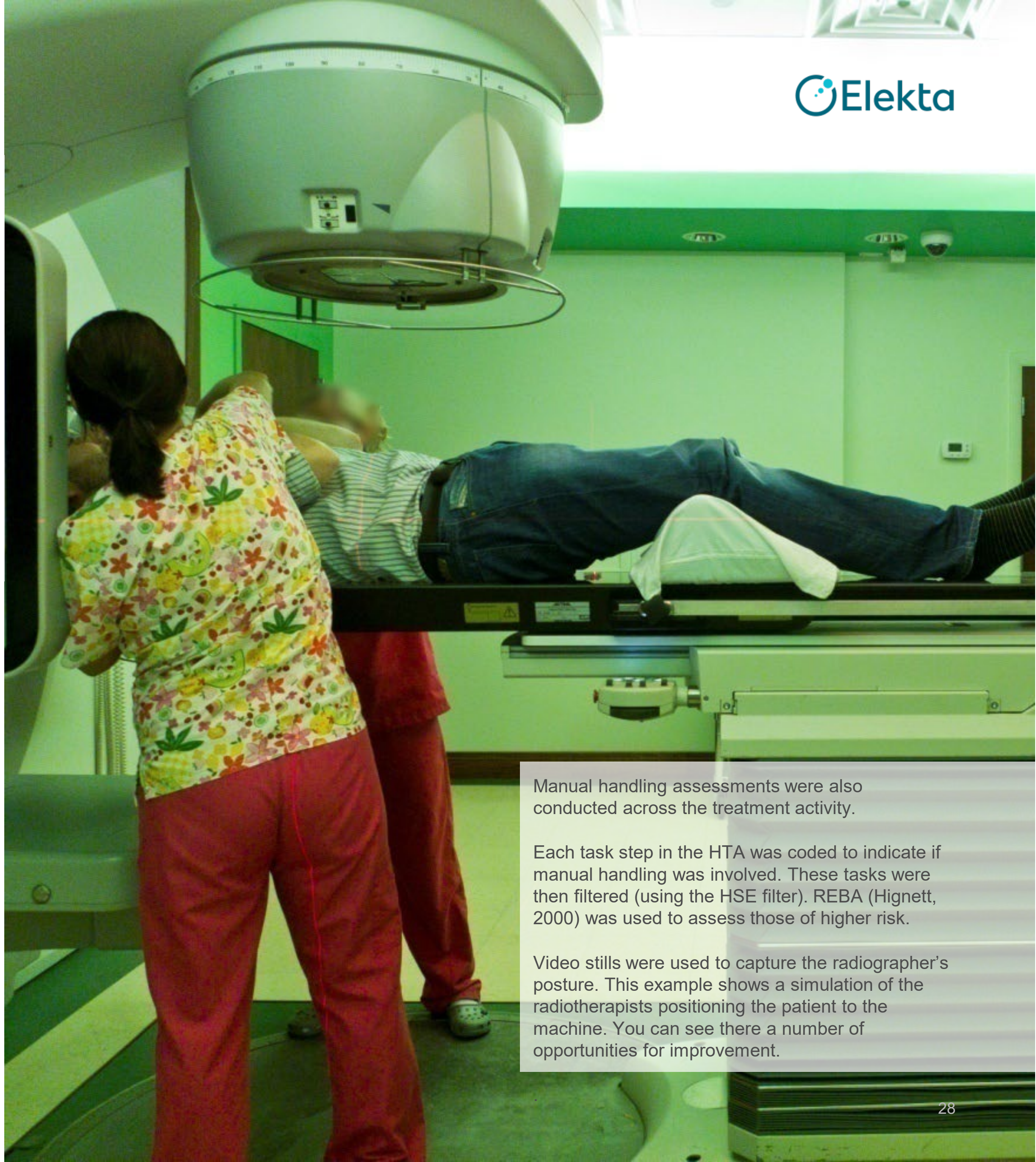

Manual handling assessments were also conducted across the treatment activity.

Each task step in the HTA was coded to indicate if manual handling was involved. These tasks were then filtered (using the HSE filter). REBA (Hignett, 2000) was used to assess those of higher risk.

Video stills were used to capture the radiographer's posture. This example shows a simulation of the radiotherapists positioning the patient to the machine. You can see there a number of opportunities for improvement.

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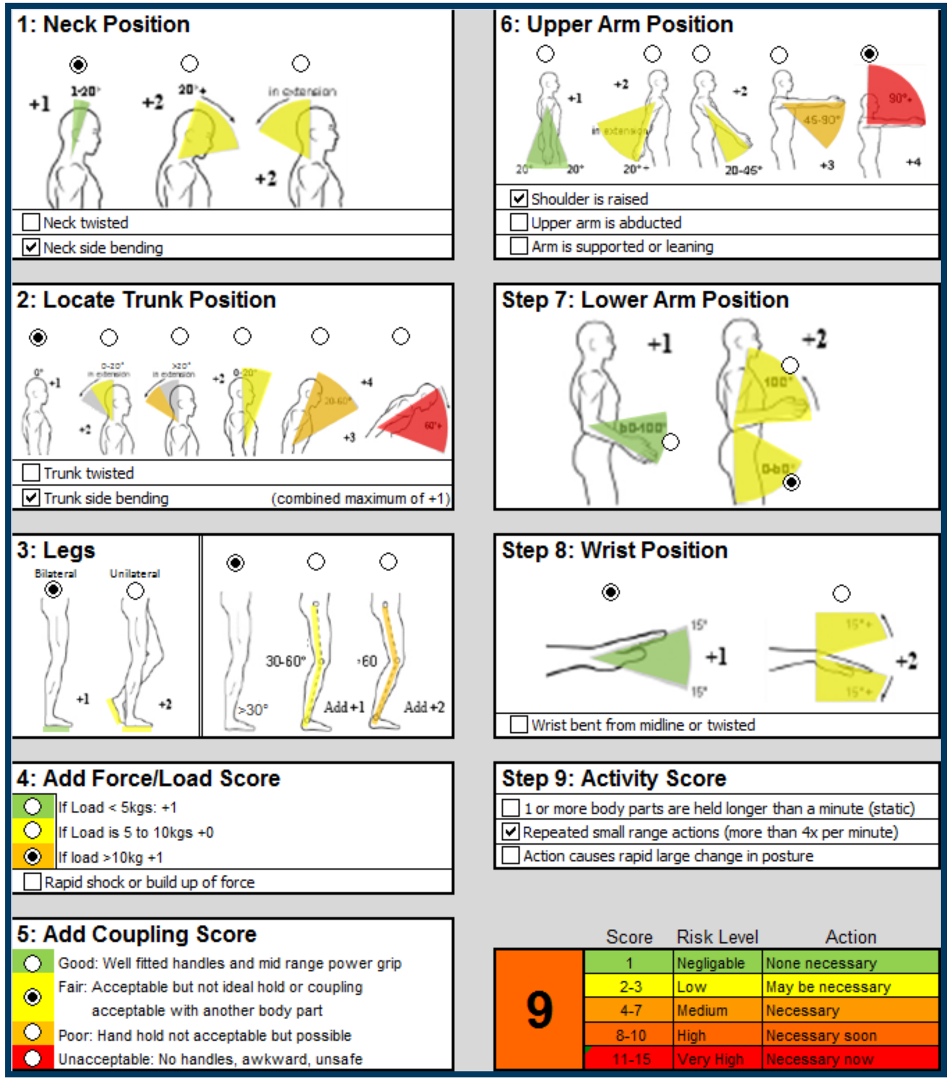
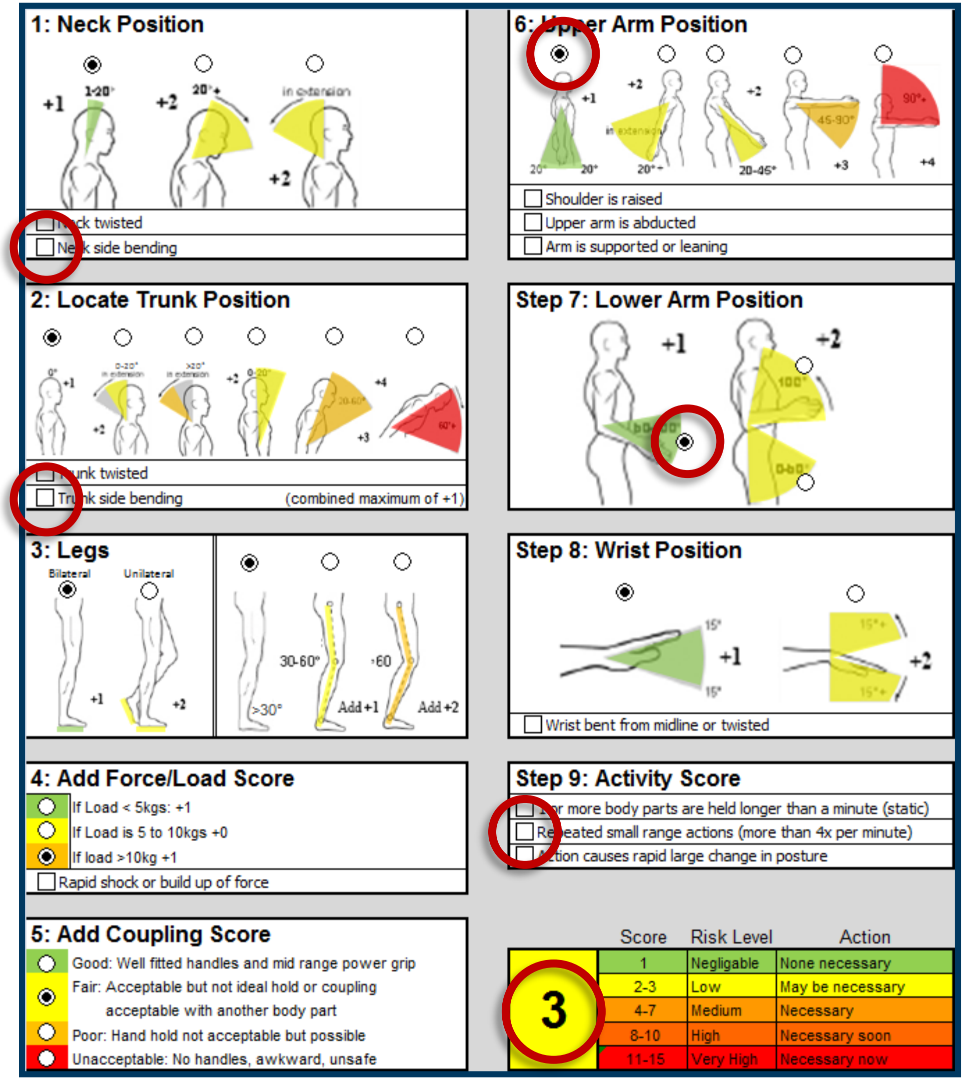
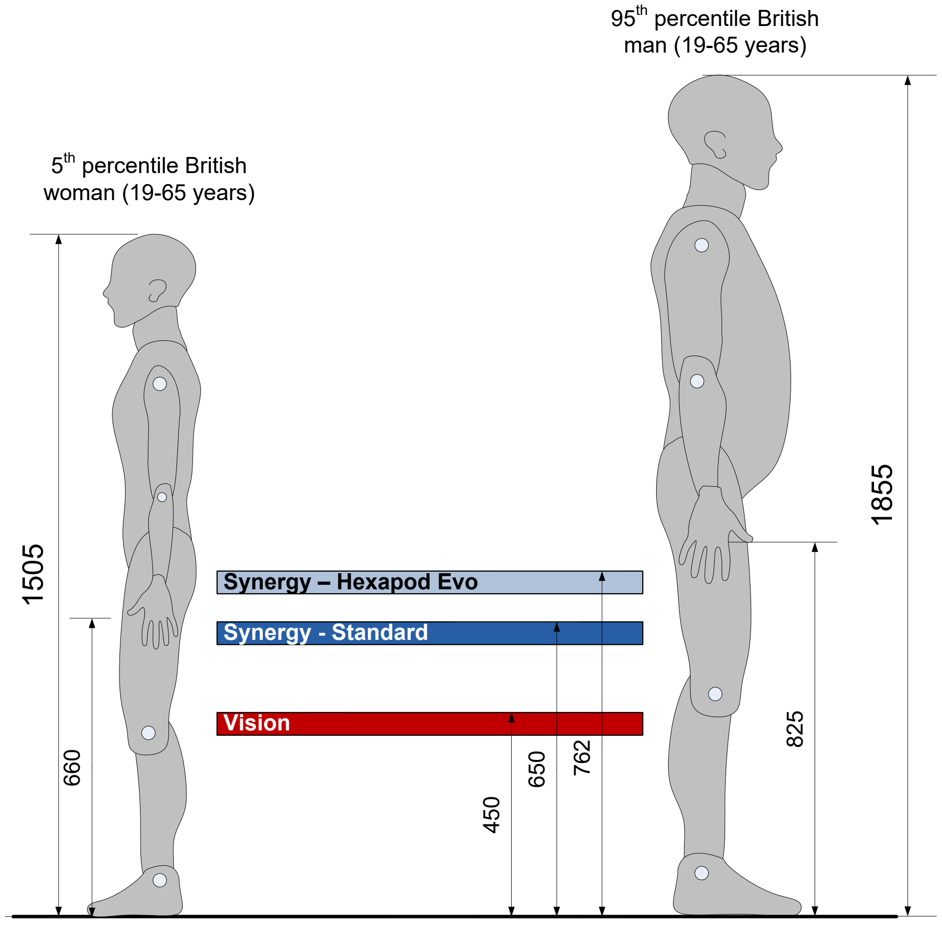


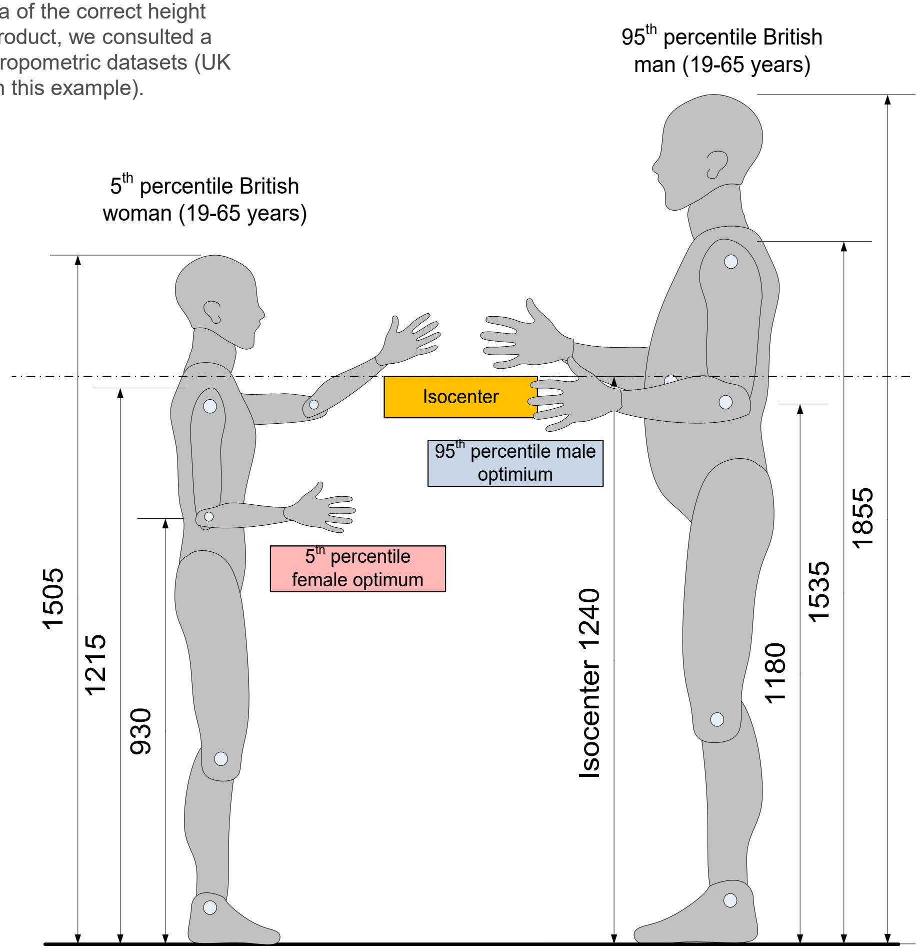
By reducing the height of the table for setup, the risk to the operators can be greatly reduced – as shown on the example on the right





All dimensions in mm, based upon Pheasant & Haslegrave (2006) Table 10.1, without shoes

To get an idea of the correct height for a global product, we consulted a range of anthropometric datasets (UK data shown in this example).



All dimensions in mm, based upon Pheasant & Haslegrave (2006) Table 10.1, without shoes

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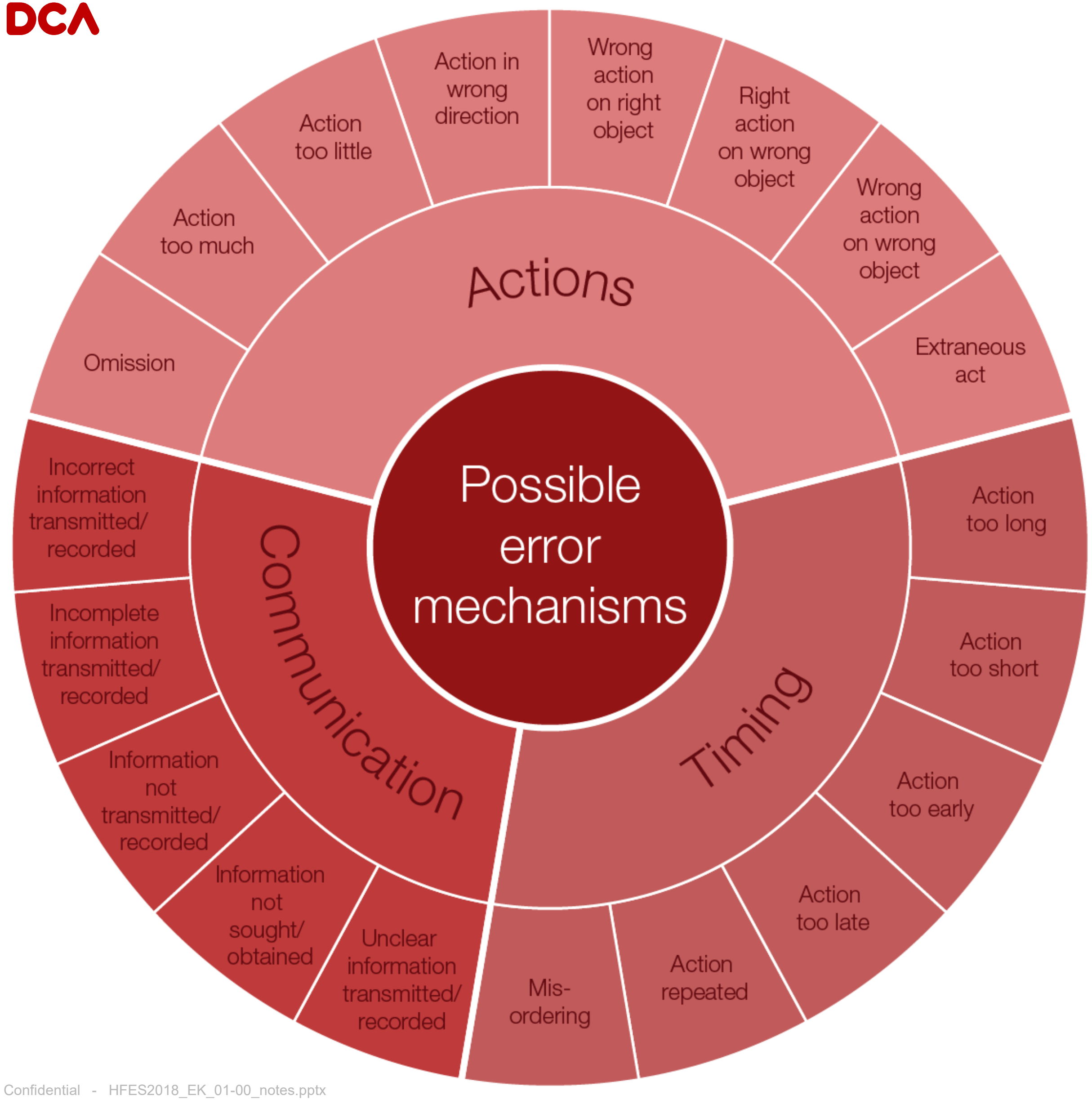
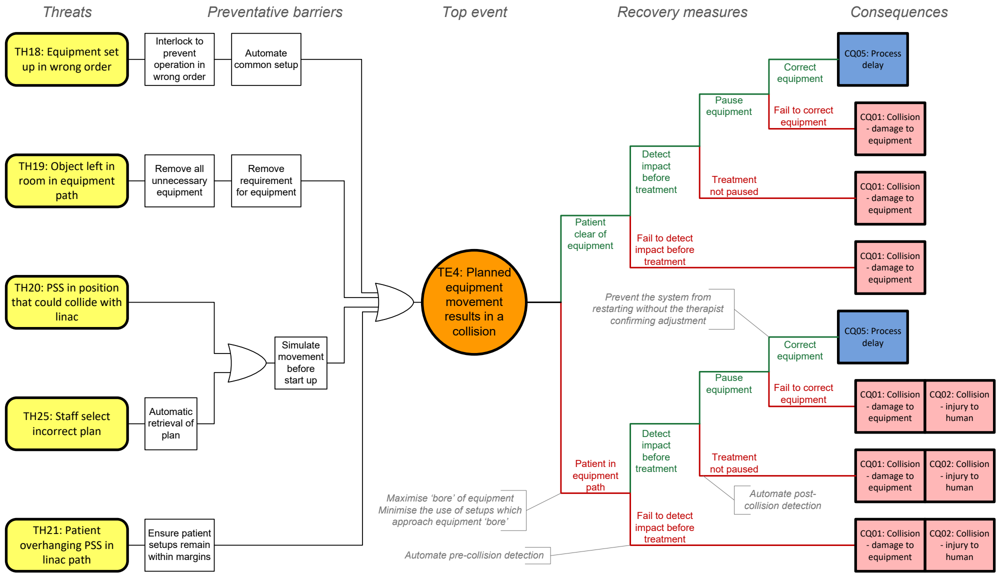


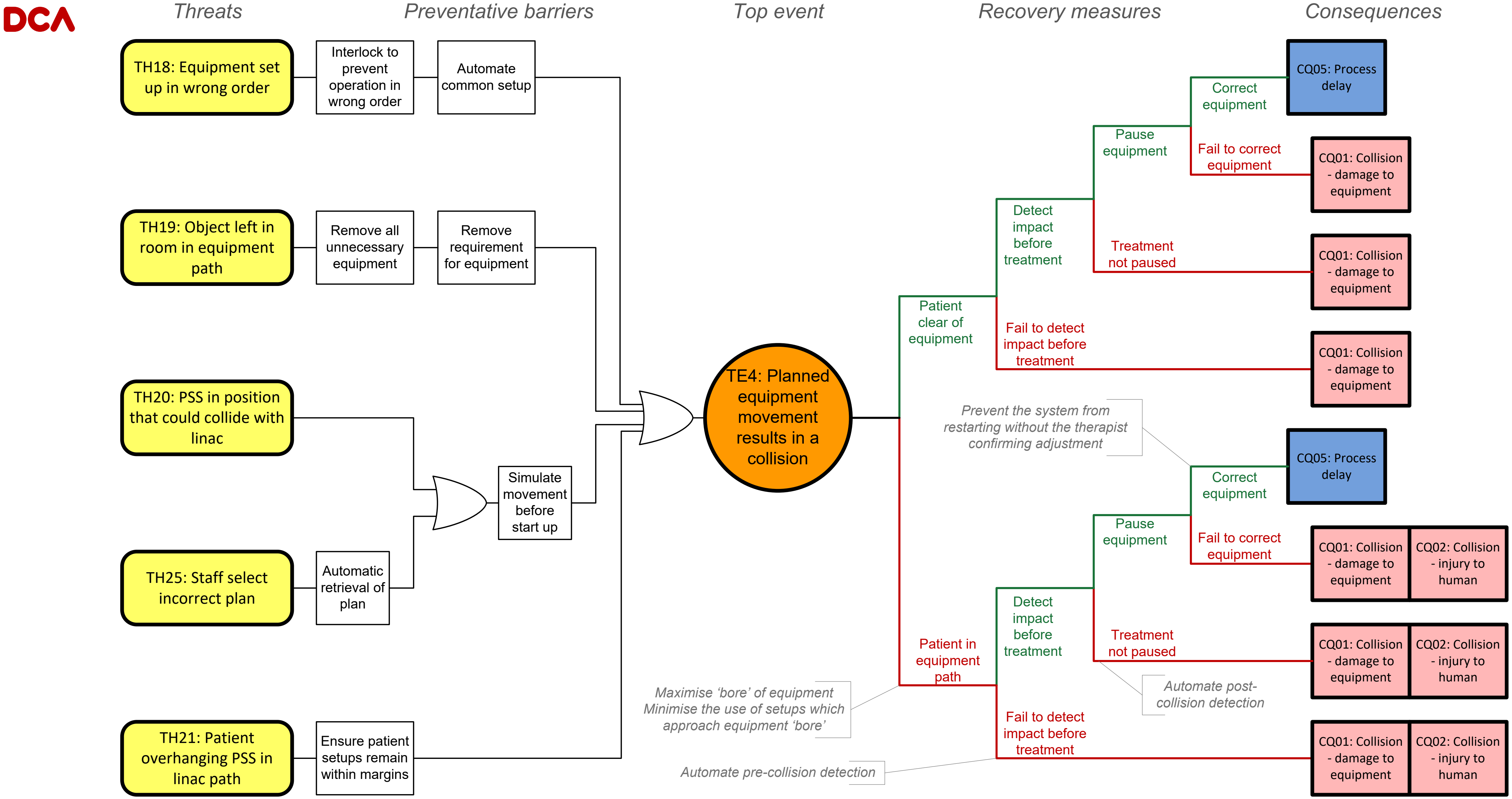
To understand error, we used a structured process for human error identification bases on TRACEr (Shorrock & Kirwan, 1999, 2002).

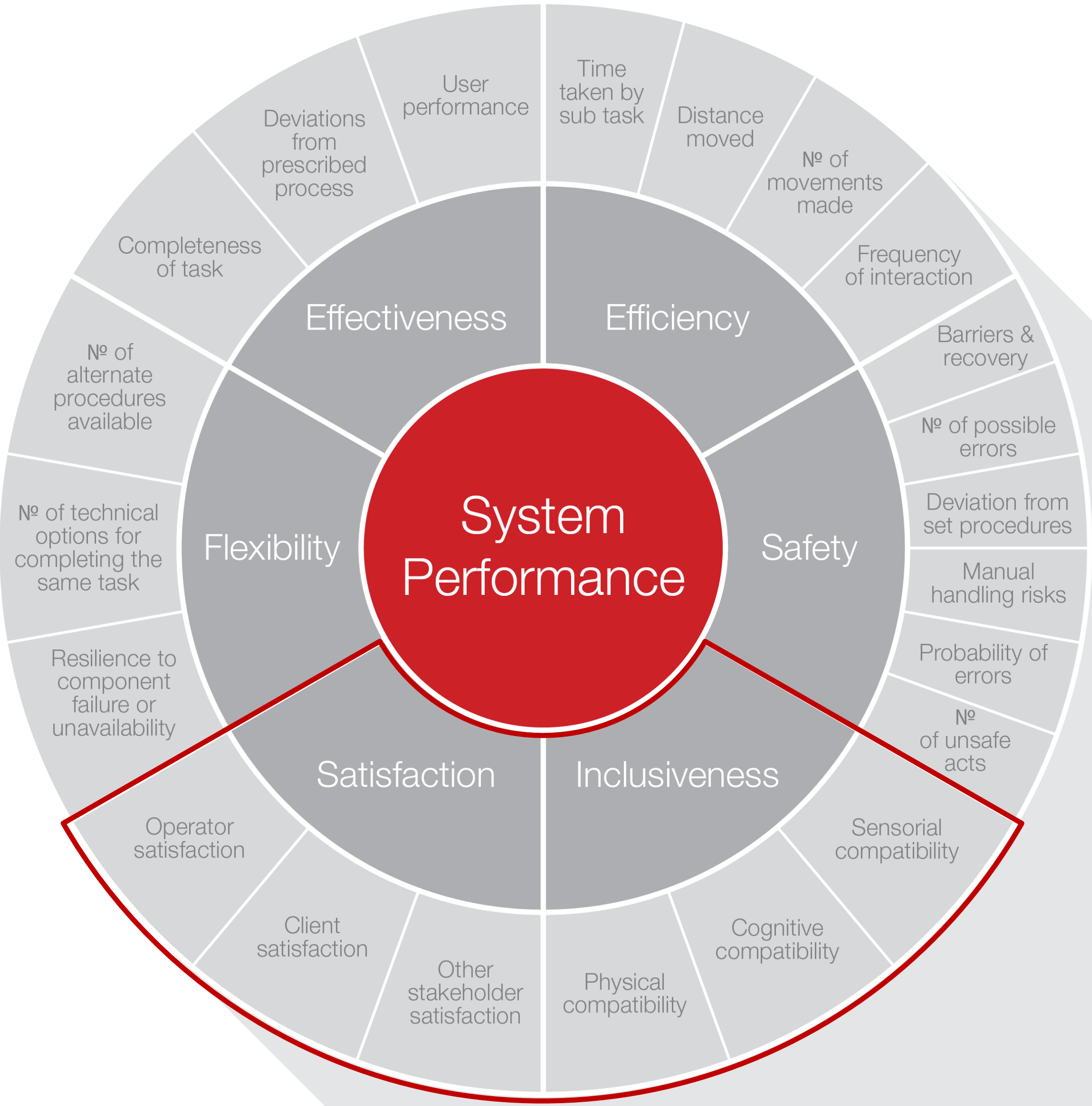
Each task step was considered against the keywords around the wheel.

Errors were then summarised in bowtie diagrams. These were used to create preventative barriers and recovery measures.

Given the repeatable and mechanistic nature of the task, this approach revealed some rich insights.




DCA
Threats
Preventative barriers
Top event
Recovery measures
Consequences
TH18: Equipment set up in wrong order
Interlock to prevent operation in wrong order
Automate common setup
TH19: Object left in room in equipment path
Remove all unnecessary equipment
Remove requirement for equipment
TH20: PSS in position that could collide with linac
Simulate movement before start up
TH25: Staff select incorrect plan
Automatic retrieval of plan
TH21: Patient overhanging PSS in linac path
Ensure patient setups remain within margins
TE4: Planned equipment movement results in a collision
Patient clear of equipment
Detect impact before treatment
Pause equipment
Correct equipment
CQ05: Process delay
Fail to correct equipment
CQ01: Collision - damage to equipment
Treatment not paused
CQ01: Collision - damage to equipment
Fail to detect impact before treatment
CQ01: Collision - damage to equipment
Prevent the system from restarting without the therapist confirming adjustment
Patient in equipment path
Detect impact before treatment
Pause equipment
Correct equipment
CQ05: Process delay
Fail to correct equipment
CQ01: Collision - damage to equipment
CQ02: Collision - injury to human
Treatment not paused
CQ01: Collision - damage to equipment
CQ02: Collision - injury to human
Automate post-collision detection
Fail to detect impact before treatment
CQ01: Collision - damage to equipment
CQ02: Collision - injury to human
Maximise 'bore' of equipment Minimise the use of setups which approach equipment 'bore'
Automate pre-collision detection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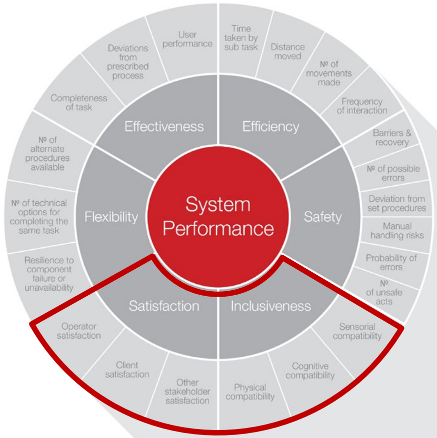
Inclusiveness & usability
Physical
(action)
Mobility
(access require-ments, accept-able distances)
Strength
(acceptable forces, grips and forms)
Flexibility
(achievable and comfortable pos-tures)
Dexterity
(acceptable forms and operations)
Reach
(acceptable heights and off-sets)
Sensory
(perception)
Sight
(field of view, colour, contrast, acuity)
Hearing
(sound detection, speech discrimina-tion, localisation)
Touch
(including proprioception)
Smell
(cues, discrimi-nation, prefer-ences)
Taste
(cues, discrimi-nation, prefer-ences)
Cognitive
Memory
(working, long term)
Problem solving
Commun-ication
(literacy, verbal, nonverbal)
Recognition
Attention



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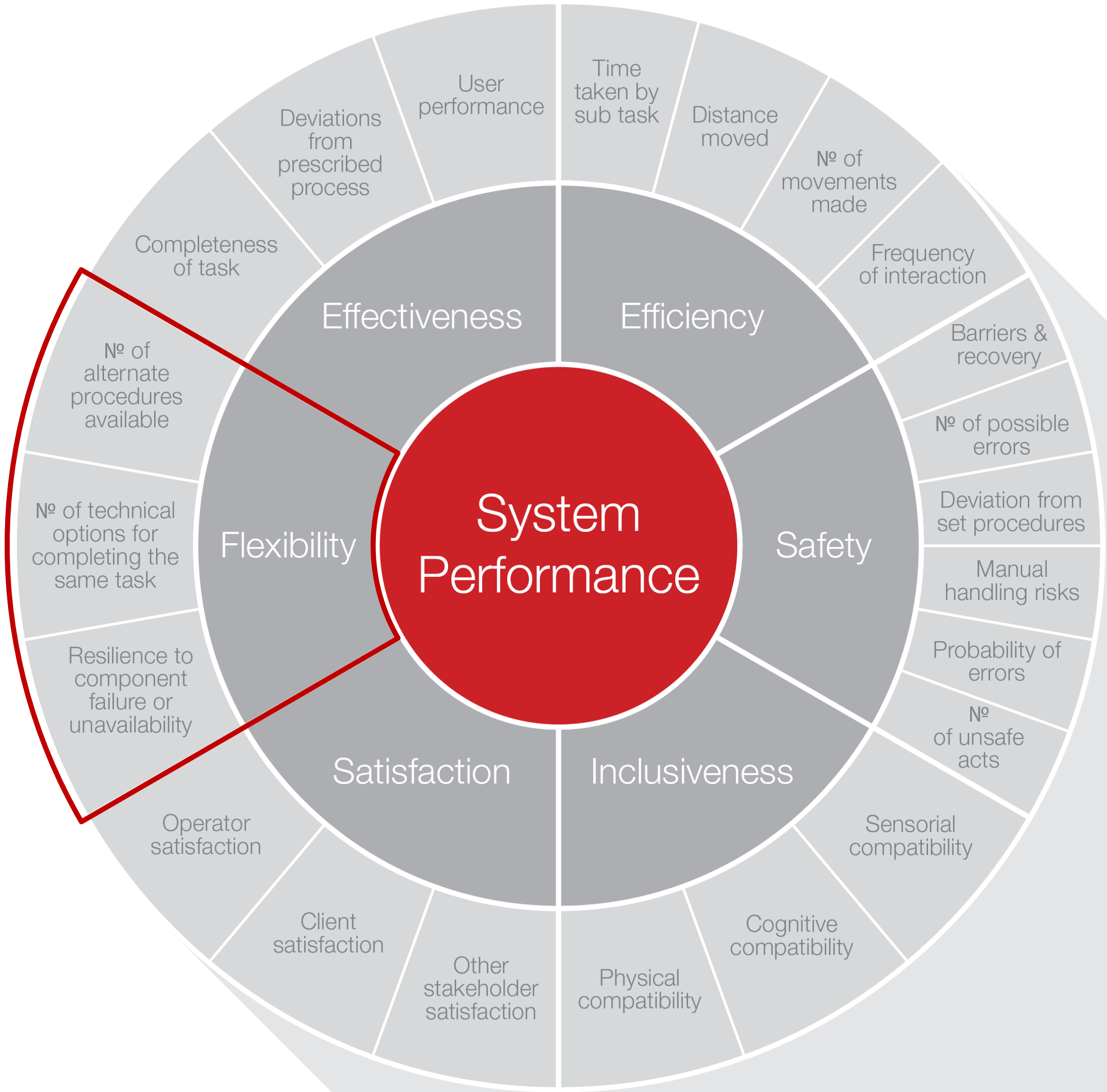
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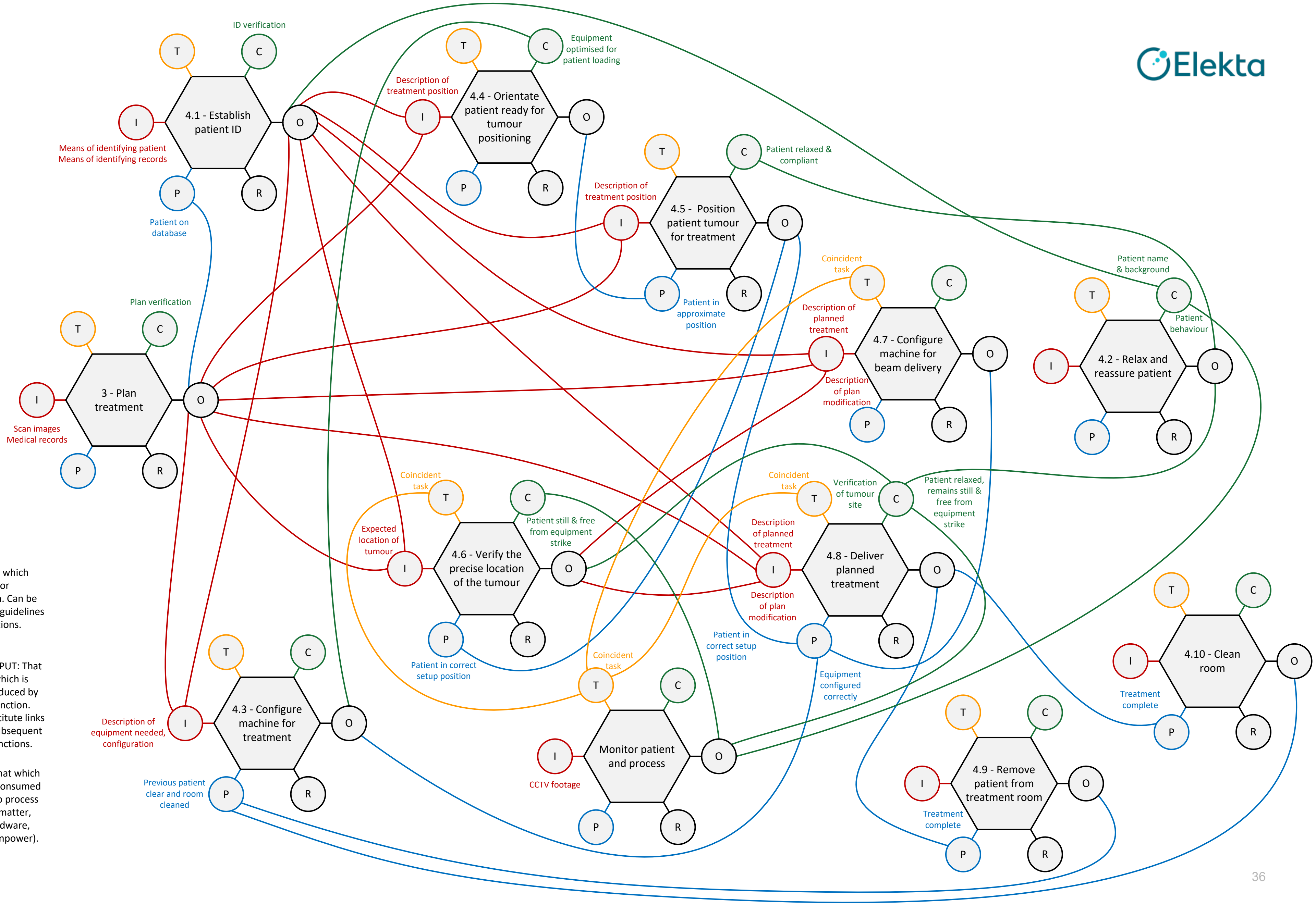
DCA

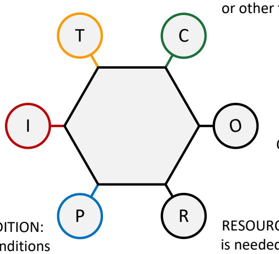
FRAM

The diagram shows the interrelationships between treatment phases as identified in the HTA



TIME available: This can be a constraint but can also be considered as a special kind of resource.

CONTROL: That which supervises or adjusts a function. Can be plans, procedures, guidelines or other functions.



INPUT: That which is used or transformed to produce the output. Constitutes the link to previous functions.

OUTPUT: That which is produced by function. Constitute links to subsequent functions.

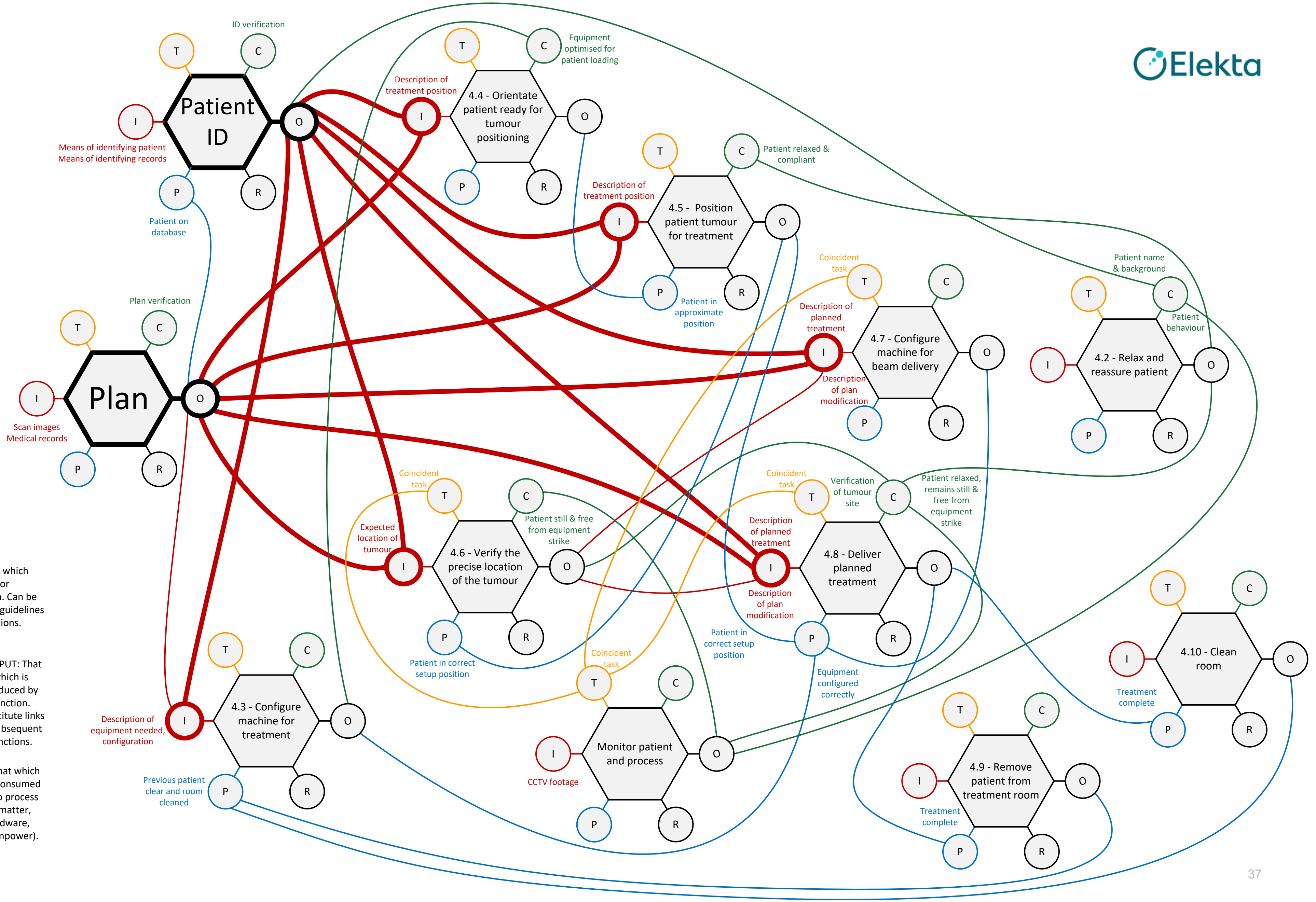
PRECONDITION: System conditions that must be fulfilled before a function can be carried out.

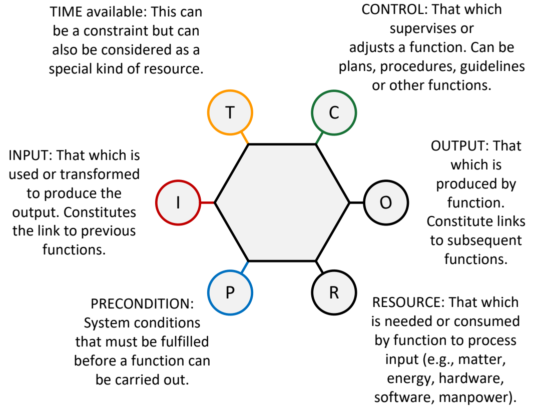
RESOURCE: That which is needed or consumed by function to process input (e.g., matter, energy, hardware, software, manpower).

FRAM

The outputs from the patient ID and the planning process are critical

Verification is key





Information emerged as a key theme for this project. Thus, the aim is to generate models to establish, what information is required, when and where it needs to be displayed, who to, and in what format.

1. What information is required?

2. When it needs to be displayed?

3. Where it should be displayed?

4. Who it should be displayed to?

5. How in what format?

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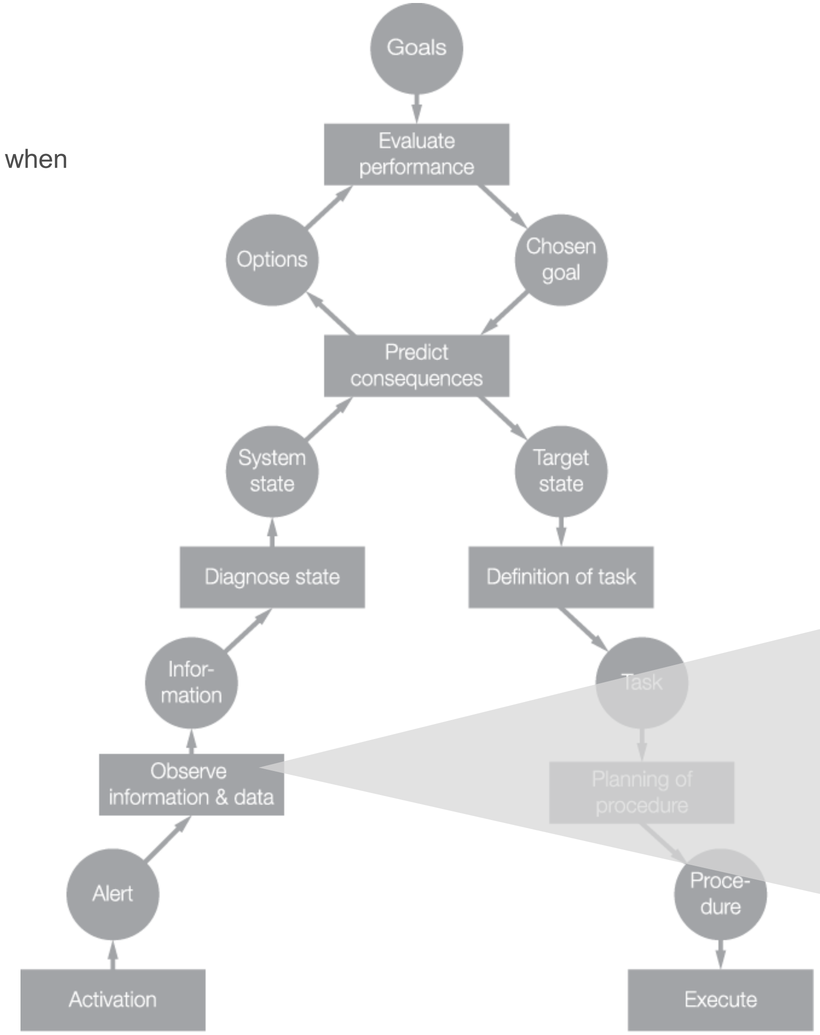
Decision ladders

36 information elements could be of use when setting up the patient



064 Who is the patient?
032 Does the patient have special medical needs?
042 Does the patient have any special cultural religious needs?
066 Is the patient a child?
067 What is the cancer type?
068 How should the patient be positioned (posture)?
008 What is the weight (size)of the patient?
009 What is the height of the patient?
015 Does the patient have physical needs?
016 Does the patient have mental needs?
069 Is the patient comfortable?
070 Is the patient relaxed?
071 Is the patient cooperative?
072 Is the patient sensitive to modesty?
052 What are the patients set up instructions?
055 What equipment is already out?
057 How many staff are available?
058 Is technical support available?
060 Where is the PSS table?
073 What are the PSS table limits?
061 Where is the hexapod?
074 What are the hexapod limits?
062 Where is the gantry?
063 Which imaging panels are deployed?
065 Where is the patient in relation to the PSS?
075 What auxiliary equipment is in the room?
053 Does the patient have personalised immobilisation devices?
054 Does the patient have personalised accessories?
076 What immobilisation aids are required?
077 What immobilisation aids are in place?
078 Which set up aids are required?
079 Which set up aids are in place?
080 Which head applicator is required?
081 Which head applicator is in place?
082 What is the equipment's movement path?
051 Are the room and equipment clean?

We also turned to Rasmussen's decision ladders to help define system information requirements.

In this example, we found that there were 36 information elements that could be of use when setting up a patient.

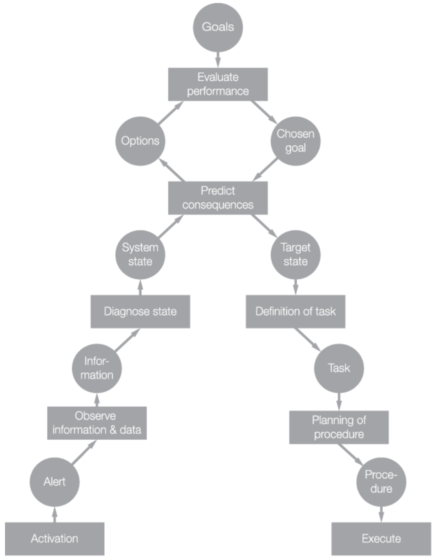
Design

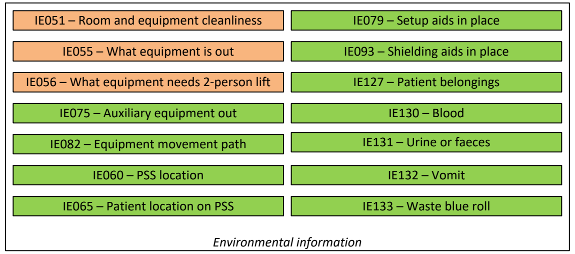
Treatment room information

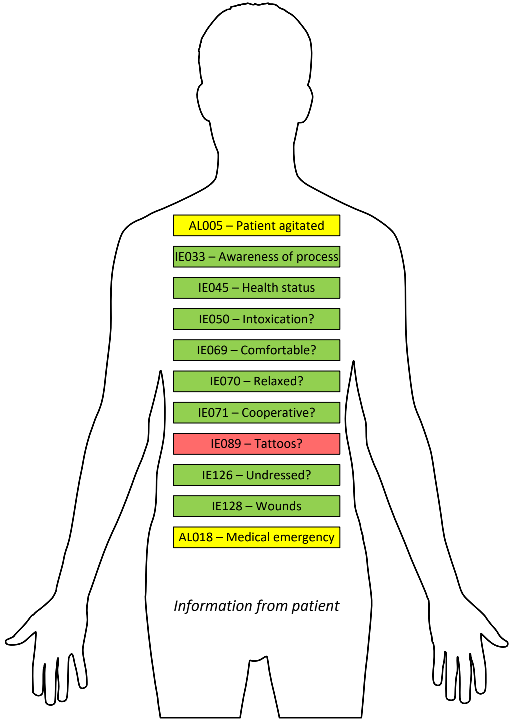
The first stage of redesigning the information displays was to plot this information out and define what was needed (green), and what could be needed (orange), for a range of situations.

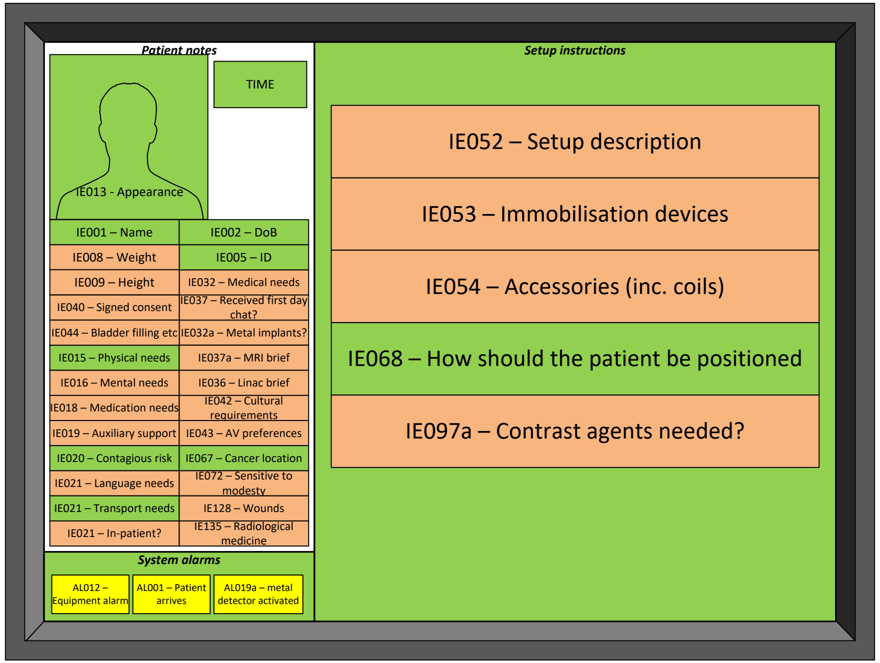
This shows an example for the treatment room information. This is clustered by information on the patient, in the environment. and on some form of display (digital or paper).

The example is for the patient loading stage. This diagram was modified for each stage.





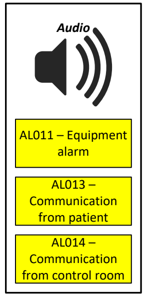




System generated information requirements

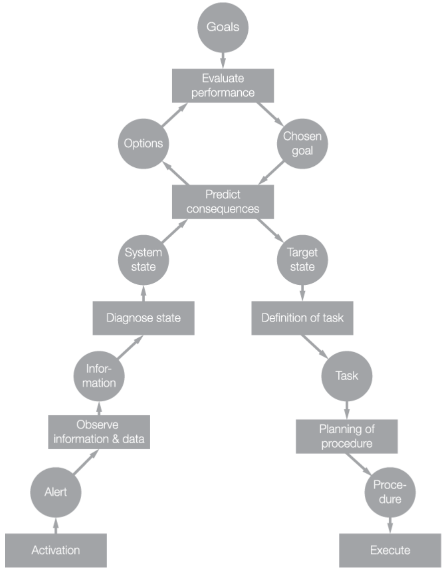
Green – Typically required at the current stage
Amber – Could be required at the current stage (may be hidden)
Red – Not required at then current stage
Yellow – Alerts to be displayed as required

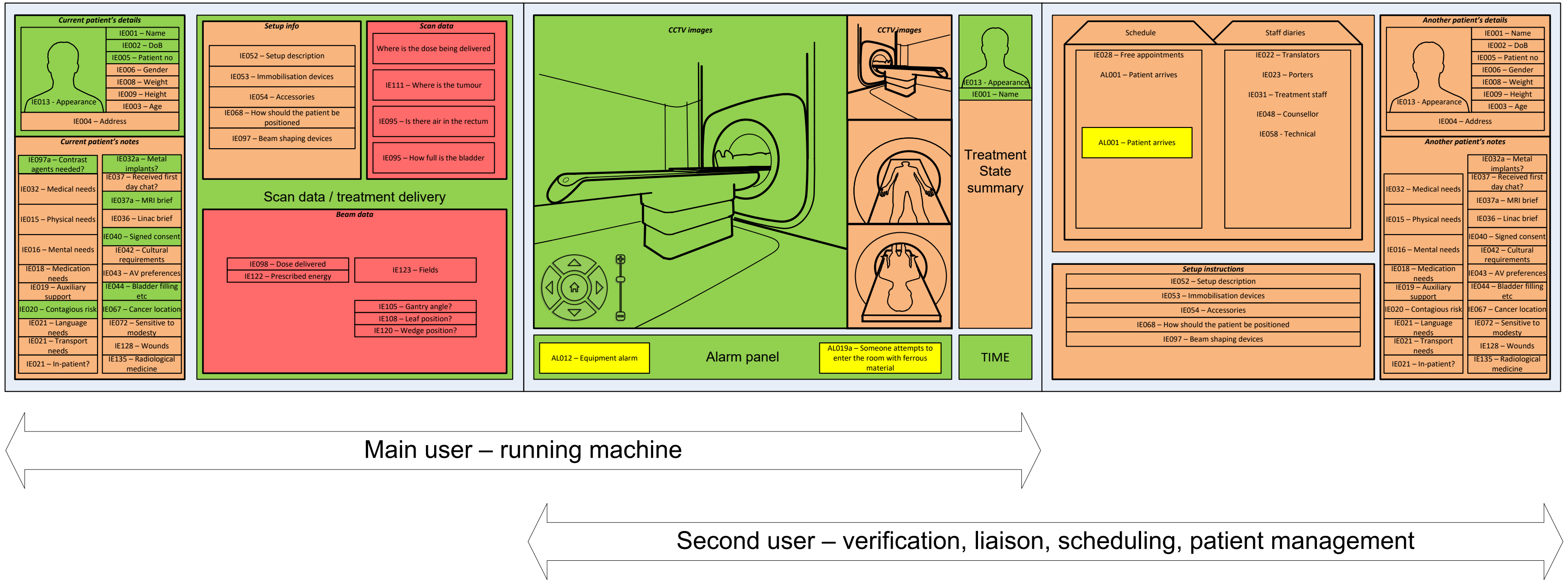
4.4 Patient loading



Control room information

We performed the same task for the control room displays. As before, a different diagram was produced for each stage of the treatment process. A split is shown highlighting the different information requirements for the two radiotherapists. One delivering the treatment and the second, verifying the treatment, liaising with other staff, manning the schedule and managing the patients.

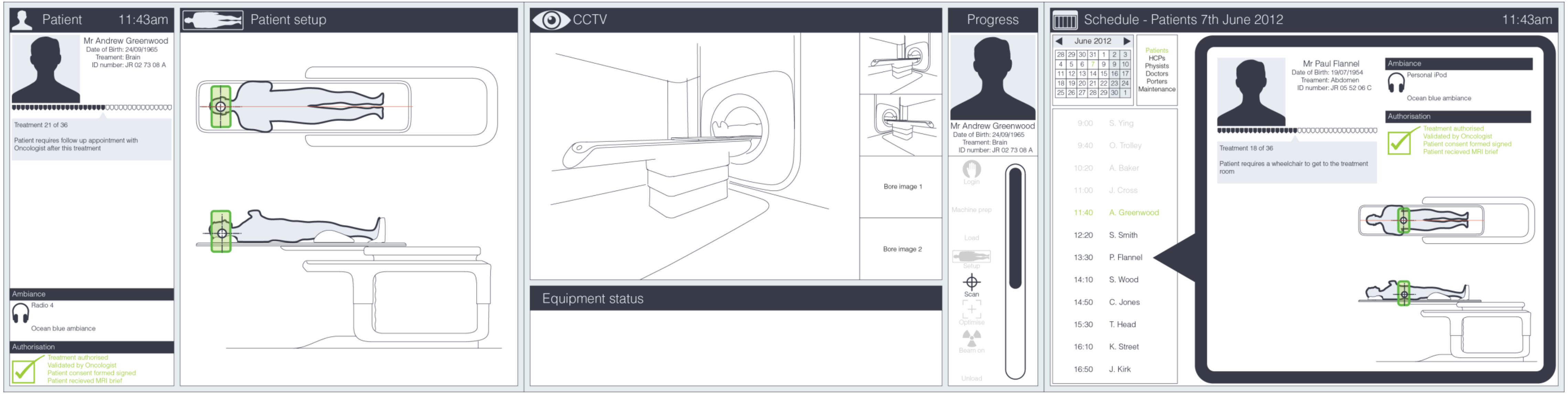




Green – Typically required at the current stage
Amber – Could be required at the current stage (may be hidden)
Red – Not required at the current stage
Yellow – Alerts to be displayed as required

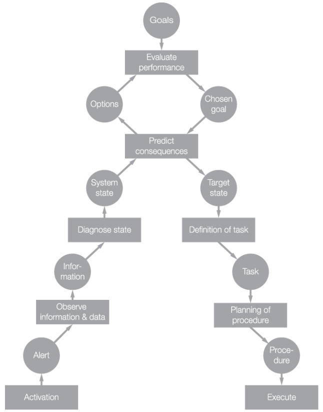
Basic wireframes were then created for each treatment stage.

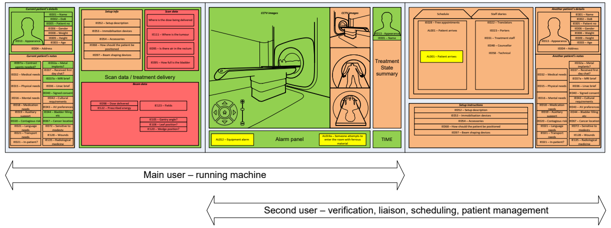
The example shows an early wireframe of the information for the control room split across three screens.

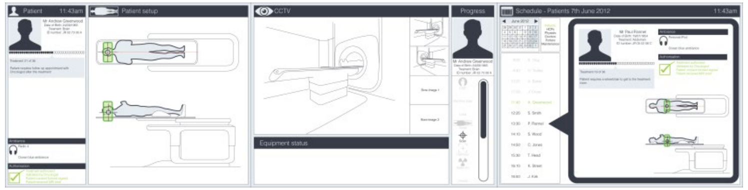


This shows the concept worked up to a higher resolution.

Thus, we had a very structured and auditable process moving from analysis using decision ladders, through specification, to wireframes and embodiment.

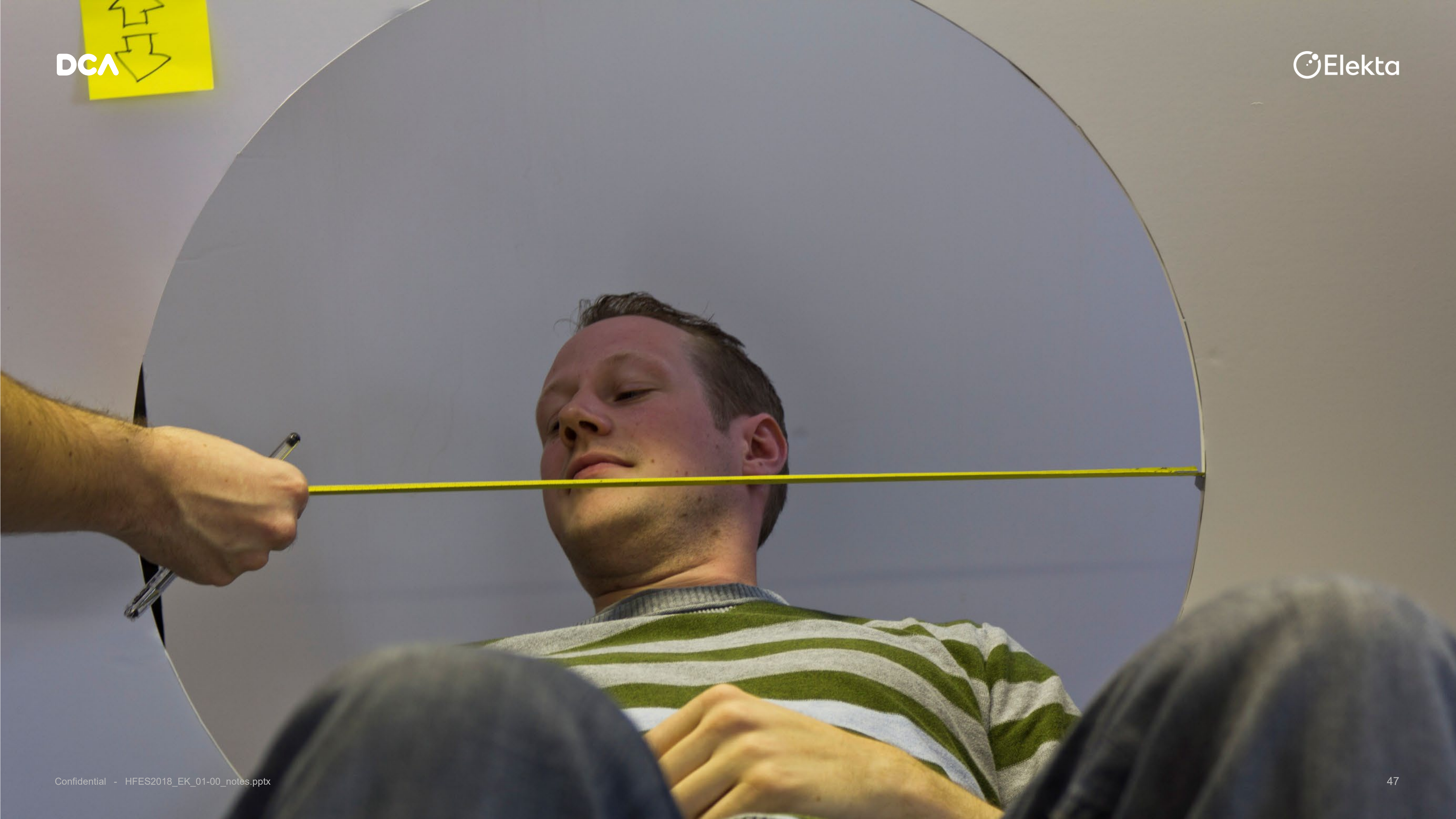


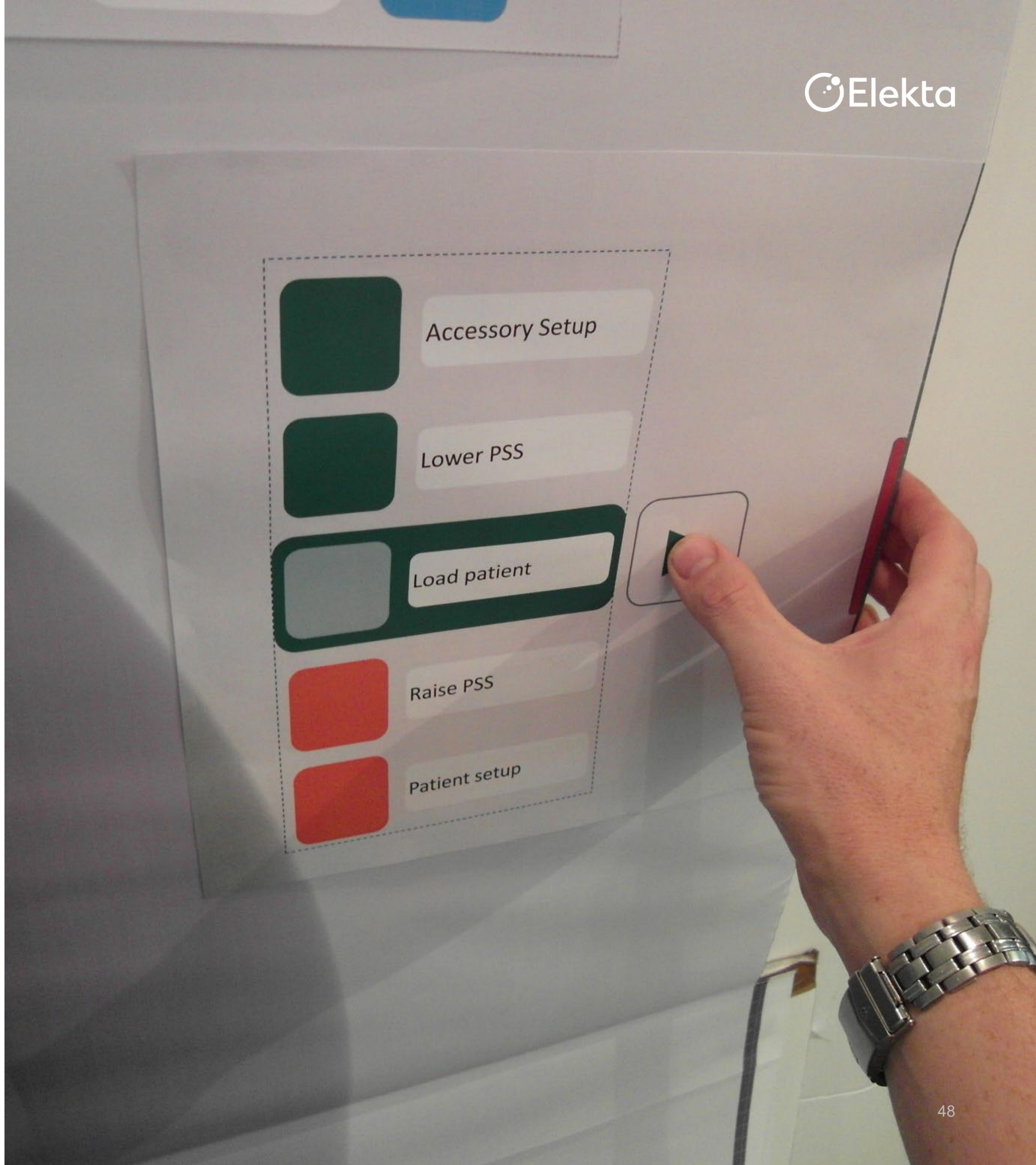




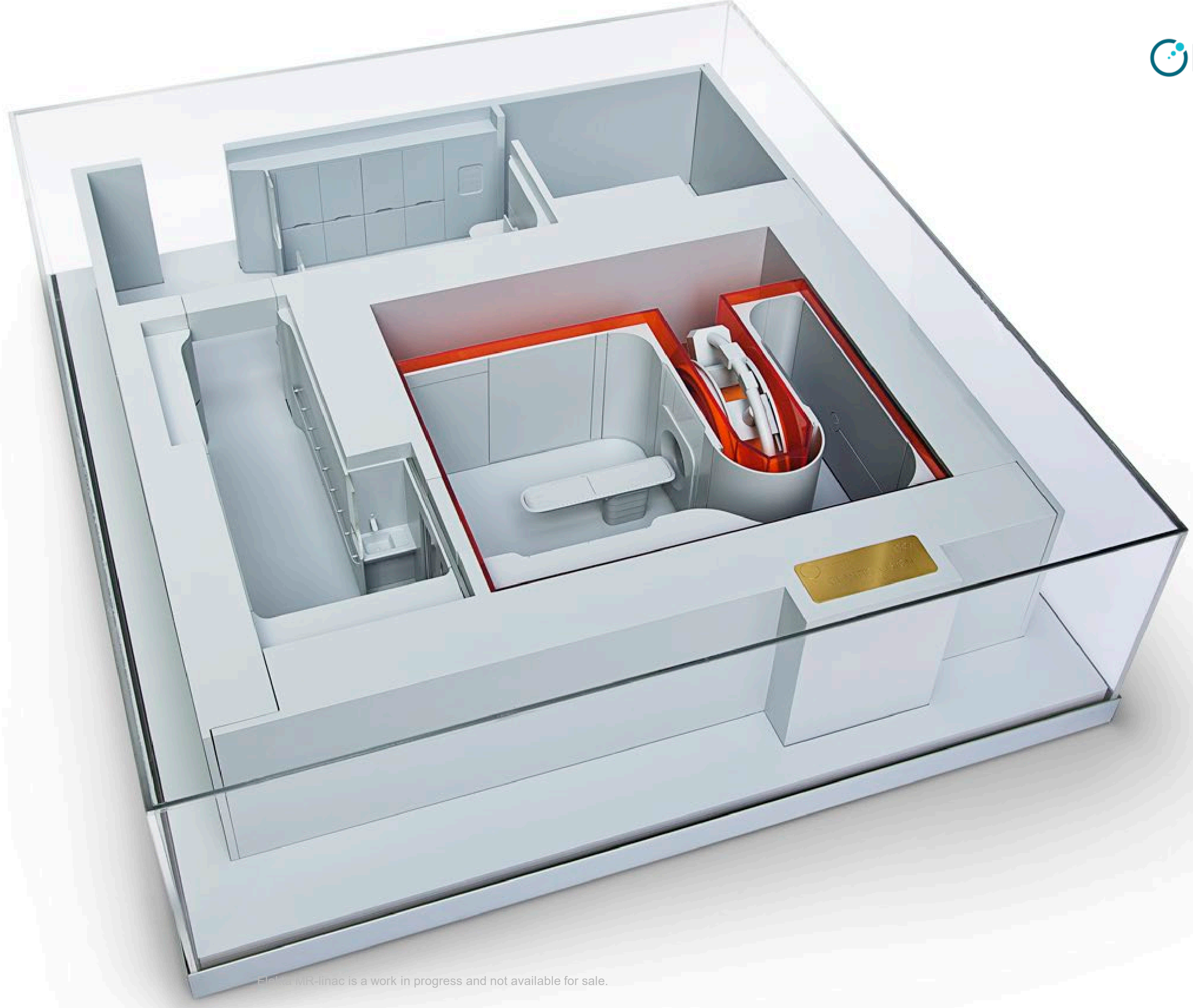
Prototyping

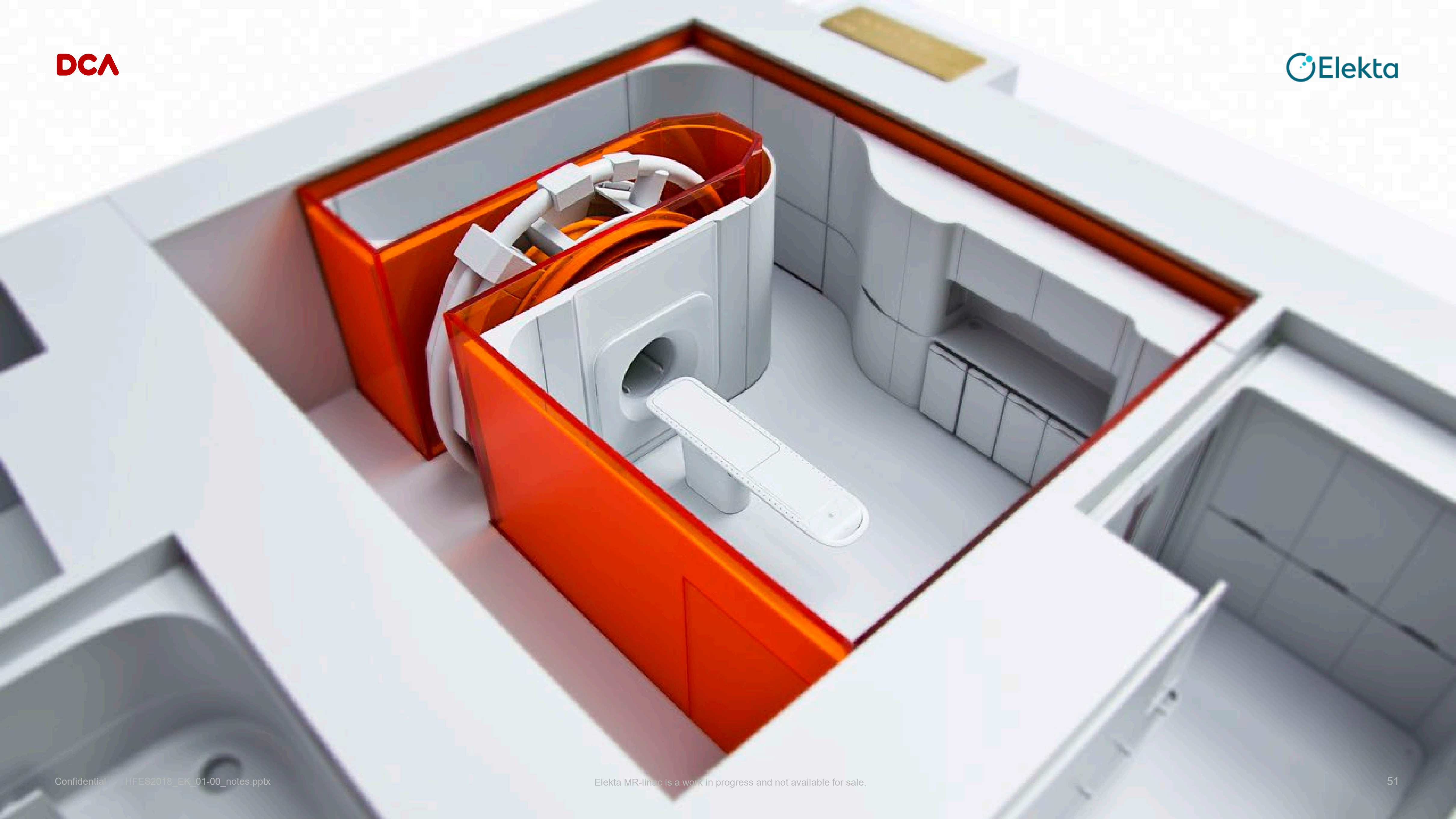
The vision was also supported by physical prototypes looking at patient experience and access to controls.




Accessory Setup
Lower PSS
Load patient
Raise PSS
Patient setup

The room environment was optimised based on radiological protection, control of magnetic fields, access, and patient experience.





Atlantic vision

The Atlantic vision was presented as an animation following a patient experience.

This shows the view in to the control room and corridor to the treatment room.

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Two separate staff workstation were proposed, one for each role. The desks are height adjustable to allow for the option to stand.

A large ‘virtual window’ provides a clear view of the treatment room.

Biometric login confirms the correct patient is entering the treatment room.

Information is provided about the progress of the treatment and selected music and lighting schemes.


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Rooms lighting is customisable.

A low table height makes getting on and off of the table much easier. Table heights can be set for individual patients. Likewise, loading heights can be set to the height of the radiotherapists.

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From vision to reality

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Sara Jones 45yr

Radiation Oncologyist

The design was developed based on a number of personas.

"I want to spend more time face to face with my patients instead of managing complicated computer systems"

Facts about Sara

Experience as a Radiation Oncologist: 10 years

Technical skills: Medium ●●●○○

Specialization: M.D.,Radiation Oncology, Head & Neck

Works at: University Hospital with:

Part of team or group:

- Radiation Oncologist Lead for the hospital's Head & Neck Tumor Advisory Board and a part of the Head & Neck multidisciplinary team
- Team lead Head & Neck national cancer guideline group

Work goals:

- Exercise best practice and evidence based Radiation

One day with Sara

IIn her daily work Sara is mostly on the run. She appreciates being able to carry out easier tasks while on the move. However, she prefers to sit down at her desk occasionally to focus on more complicated cases. She has a desk of her own at the doctors' office where she can work peacefully, but she doesn't mind using the workstations in the planning room or doing simpler tasks when logged in from her private laptop at home

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Mary Rogers 27yr

Medical Dosimetrist/Planner

"I take pride in helping my team deliver great care by making sure that I create the best treatment plan for each patient."

Facts about Mary

Experience as a Dosimetrist/Planner:	3 years	
Technical skills:	Medium	●●●○○
Specialization:	Abdominal treatment planning	

Part of team or group:

- VMAT (Volumetric Modulated Arc Therapy planning) team
- AAMD(American Association of Medical Dosimetrist) member

One day with Mary

Mary works as a medical dosimetrist at a university hospital. There are five dosimetrists and one trainee in her group. The dosimetrists, physicists, and radiation oncologist working on planning tasks share a large planning room. They have a shared task list showing patients that are ready for segmentation, delineation, treatment planning or plan QA. Most days, Mary logs into her workstation in the planning room and into the systems she needs during the day: the treatment planning system, the medical record system, and the

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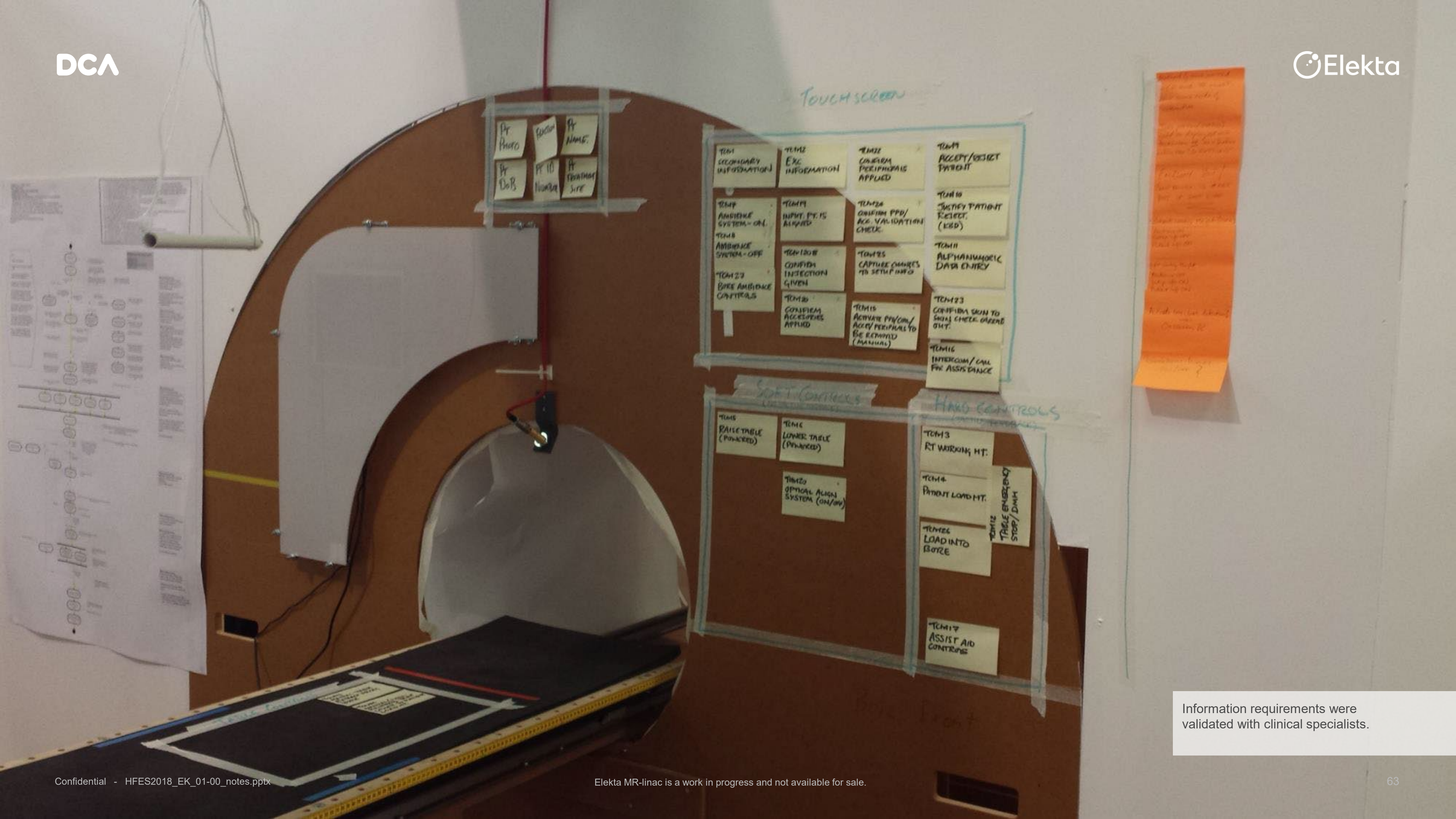
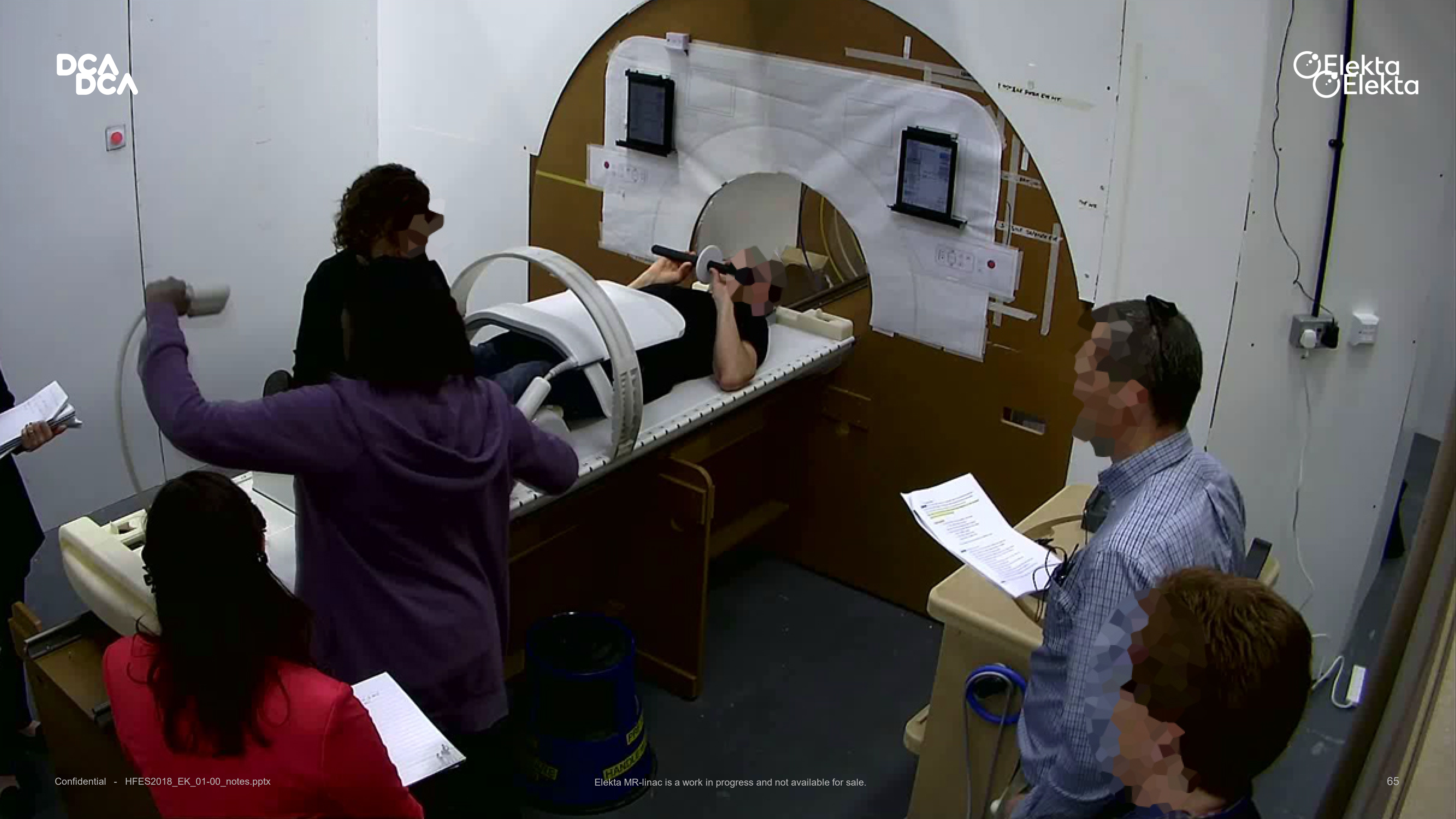
Elekta took responsibility for developing a production product informed by the vision.

The design was refined in an iterative way. Full size prototypes were built to evaluate the design against known workflows.



Information requirements were validated with clinical specialists.

And tested in simulated use workflows



Elekta MR-linac is a work in progress and not available for sale.

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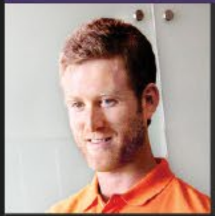
Johnson, Tony



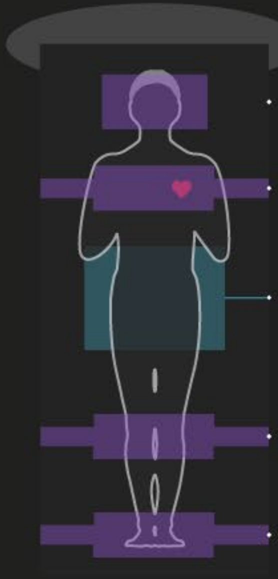
MRN: 6012111234
Oct 16, 1962 | 52 yr

Conformal Prostate
185* Prostate

Site: Prostate
Technique: IMRT
Fraction: 4/25
Attending: Susan H.

Phone: 123-456-7890
Add: 100 Mathilda Pl
Sunnyvale CA
94086

Head First Supine



5 ✓
Headrest - Supine

18 ✓
Chest Board

23 ✓
Anterior Coil

34 ✓
Knee Block Base
Knee Block

46 ✓
Feet Block

Setup Instructions:
Pacemaker...
Allergies...
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute

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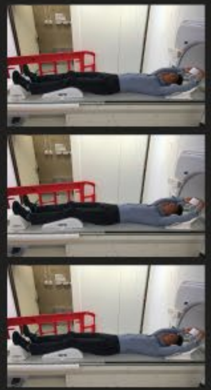


Confirm Time-Out

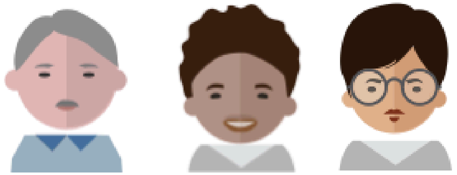
Confirm Patient Setup

Setup Patient

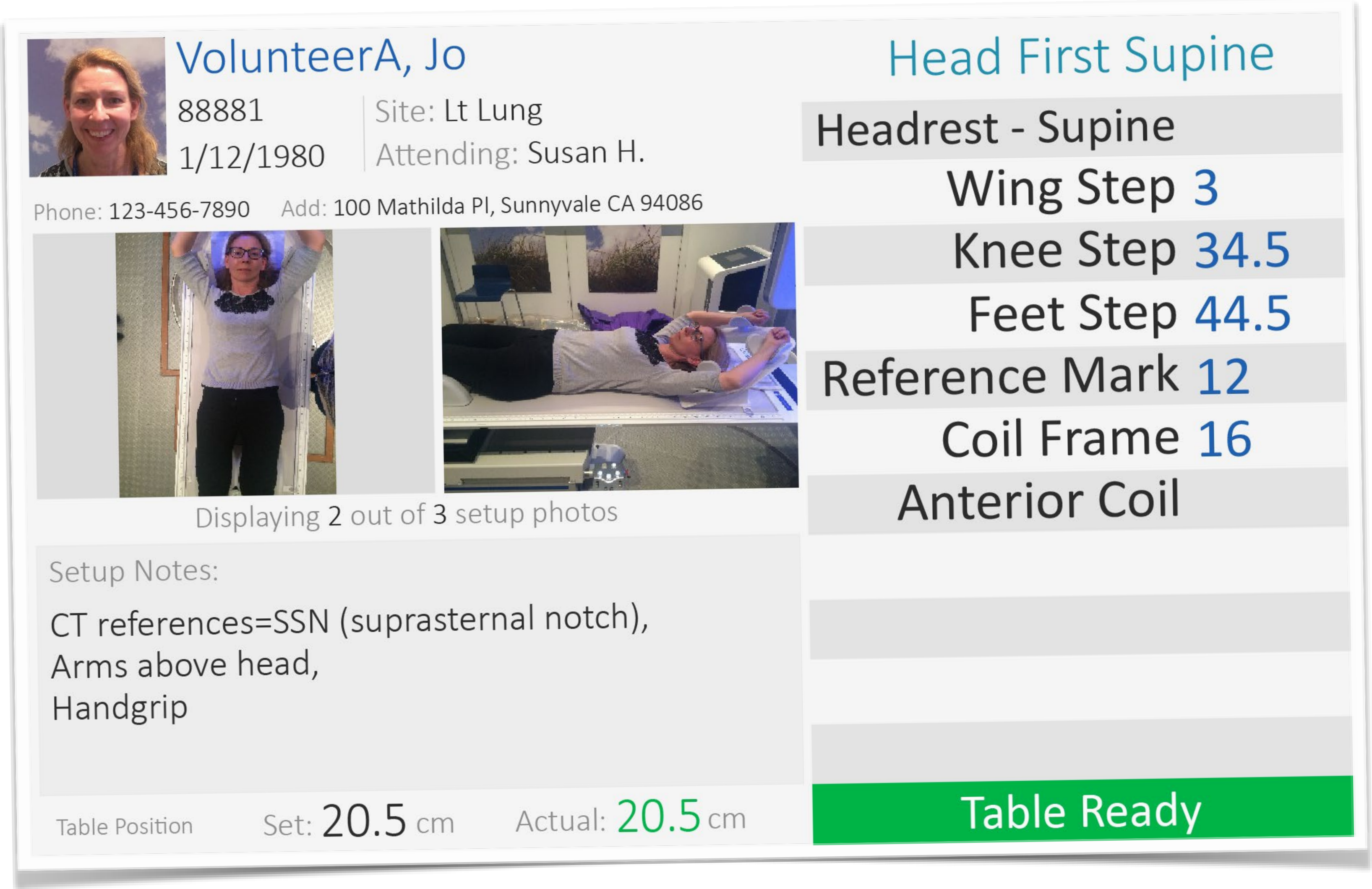
Goal
Perform patient timeout.
Prepare PPD and contrast for setup.
Immobilize patient Tony for treatment.
Load patient into treatment position.

Trigger
Patient enters Treatment Room

Actors
Patient Tony
Radiation Therapists
Anne and Steve;



Location
Treatment Room

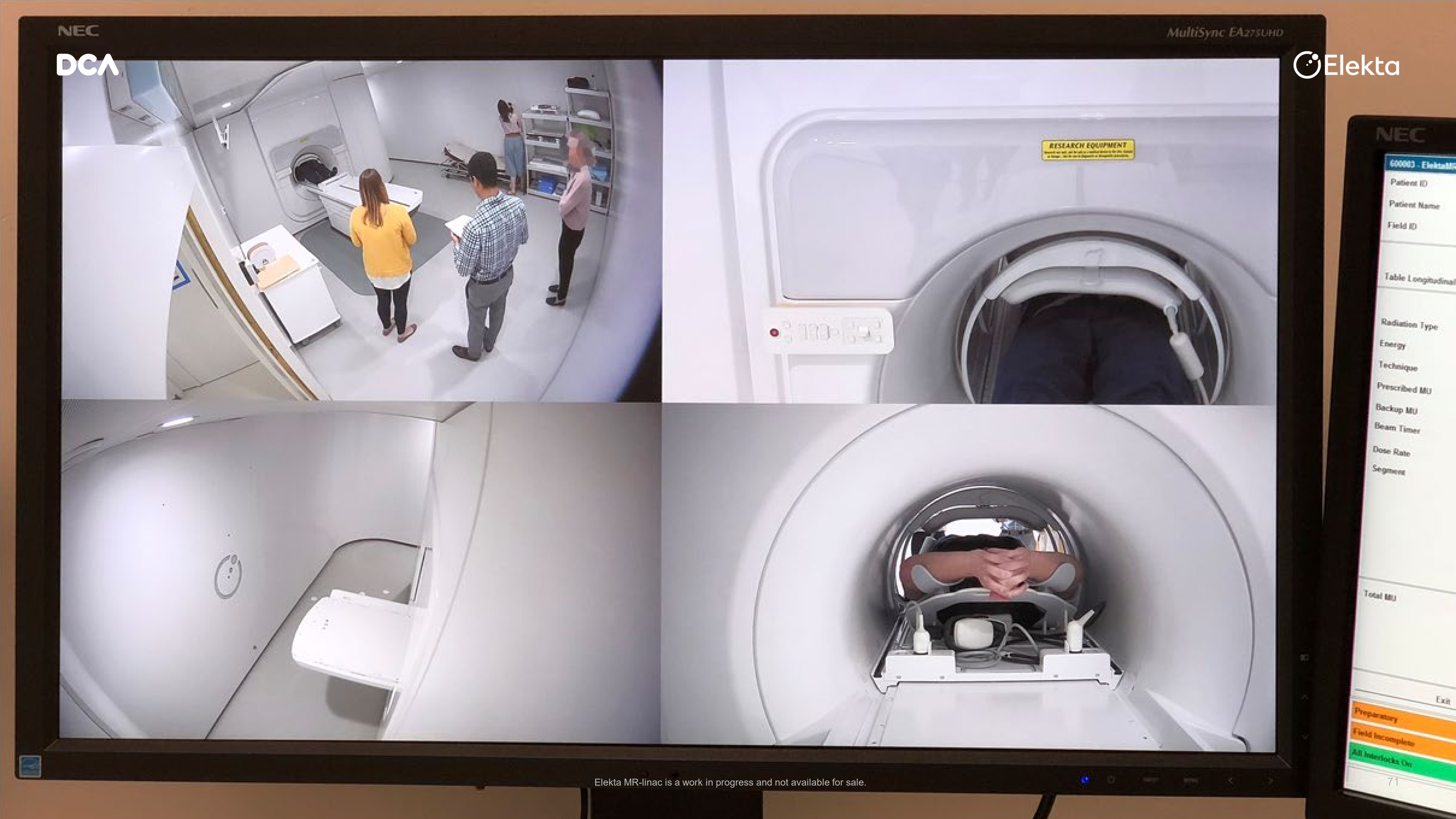


Testing was conducted throughout the development process.

Elekta MR-linac is a work in progress and not available for sale.

DCA

Elekta



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