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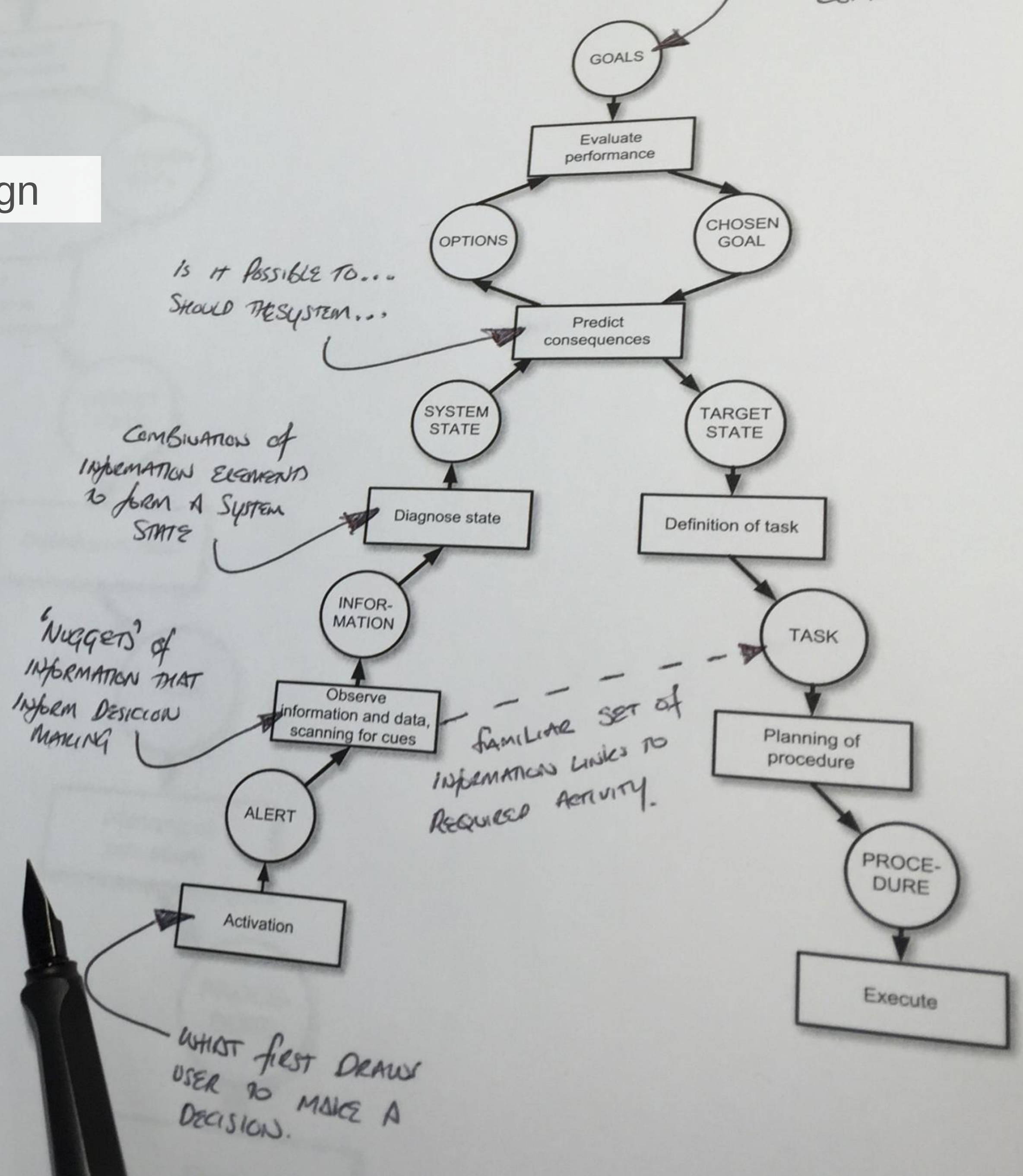
This is an annotated version of a presentation that was delivered at the Chartered Institute of Ergonomics and Human Factors (CIEHF) annual conference in April 2016.

The accompanying paper, which was awarded best paper, provides additional details.

Using the decsion ladder to reach a better design

This presentation is on a fairly niche topic… it's one of the less frequently used part of the Cognitive Work Analysis framework, which itself is fairly infrequently used – particularly in the design world.

That said, I have found it to be one of the most powerful tools in making the step from knowledge elicitation through to design, so I thought it would be a great thing to share.



Let’s start with a real world example…

You don’t have to be a human factors or UX expert to know that this is poor feedback.

MALFUNCTION 54

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What do heuristics tell us?

Nielsen & Molich, 1990

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

If we dust off any of the numerous HCI checklist documents that came out in the 80s and 90s, this kind of feedback will violate a number of them. In this case there is a poor match between the system and the real world, it requires recognition rather than recall – assuming you knew what it meant in the first place, and it does little to help you diagnose the fault.

For basic software heuristics may work well

So actually, these checklists are fairly good at helping to pick up these issues, and if you system is fairly simple that can work quite well.

What about safety critical systems?

But what happens when we move from designing alarm clock apps to safety critical systems… the consequences have now moved from oversleeping to potentially life threatening situations. In these environments there is often an abundance of information and lots of different people interacting with it.

Five questions…

So clearly what we need is some structure to considering the information available, we can get this by considering five key questions

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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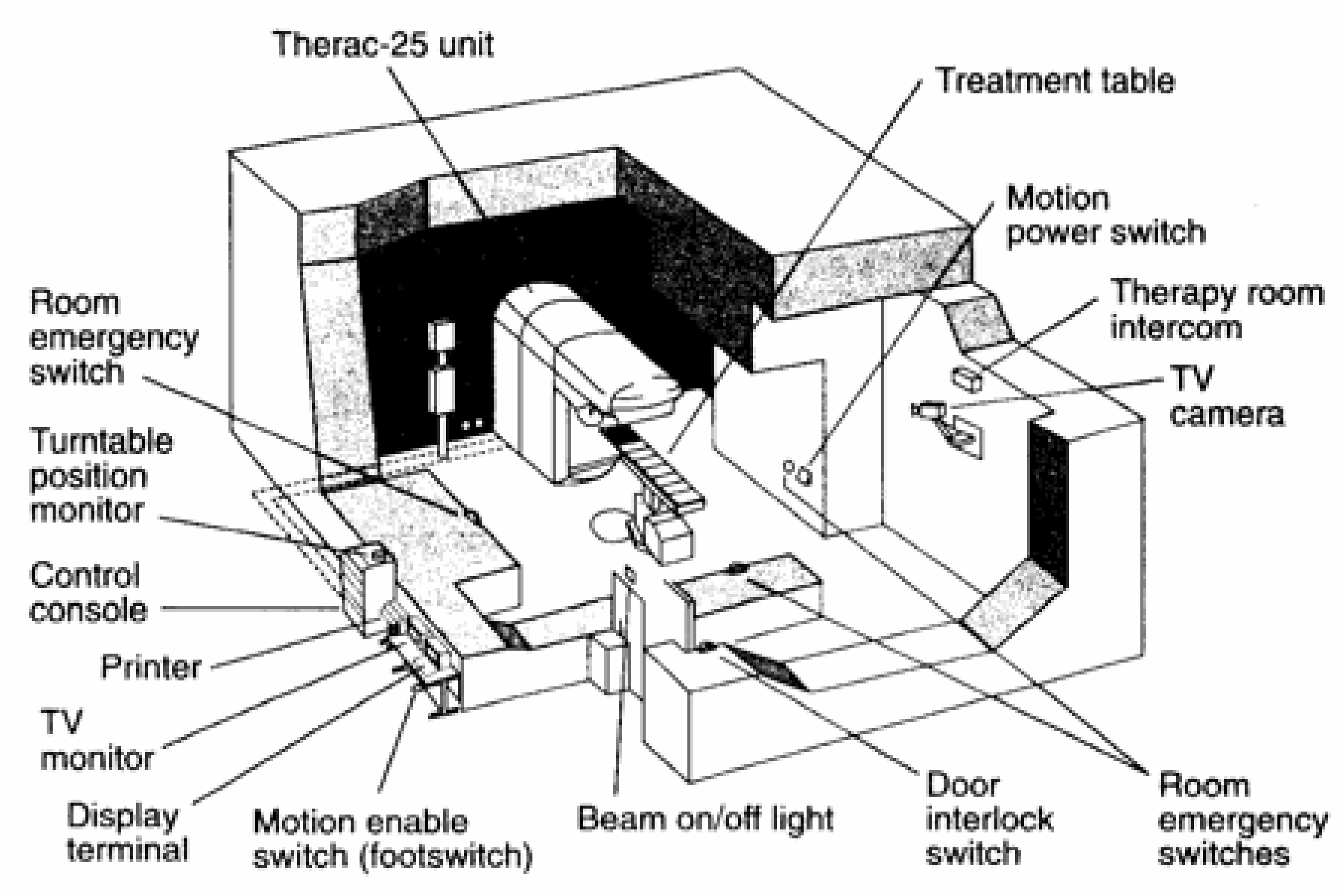
Therac-25

- Right place
- Right dose
- Right duration

We can bring this to life a bit more with an example. Some of you may have spotted this from the Malfunction 54 reference, but I have picked an old case of the Therac-25 radiography machine to explain this further. It's a case study that our keynote Nancy Leveson wrote a seminal [paper]() on.

Essentially radiotherapy works by exposing targeted areas of the body to radiation. In most cases, its used to eliminate or control the growth of tumours.

The challenge with radiotherapy as a treatment is that the radiation is also harmful to healthy tissue, thus it's critical that the radiation I delivered to the right place in the right dose.



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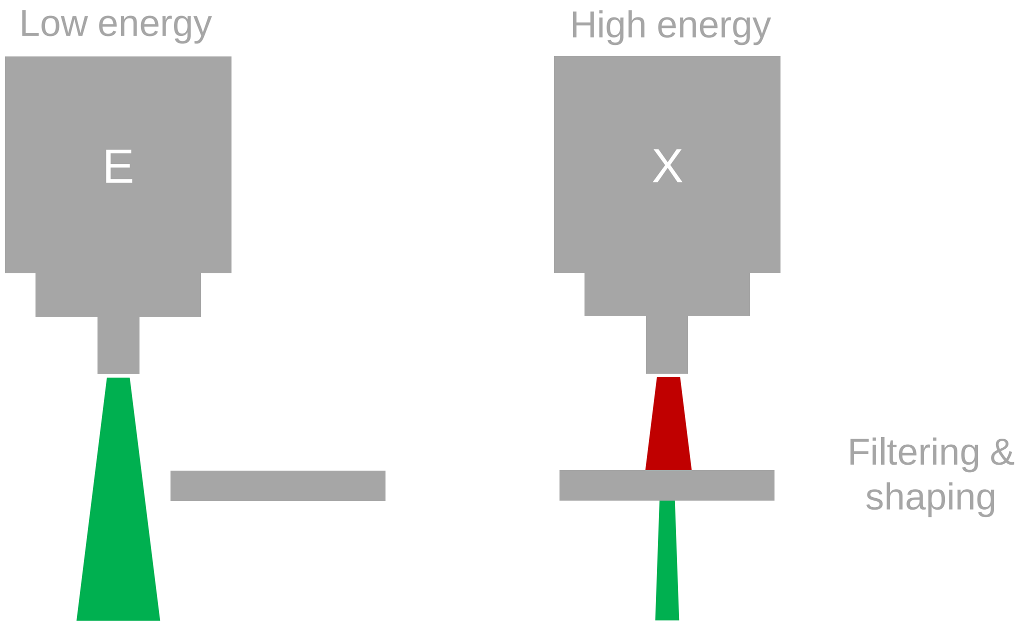
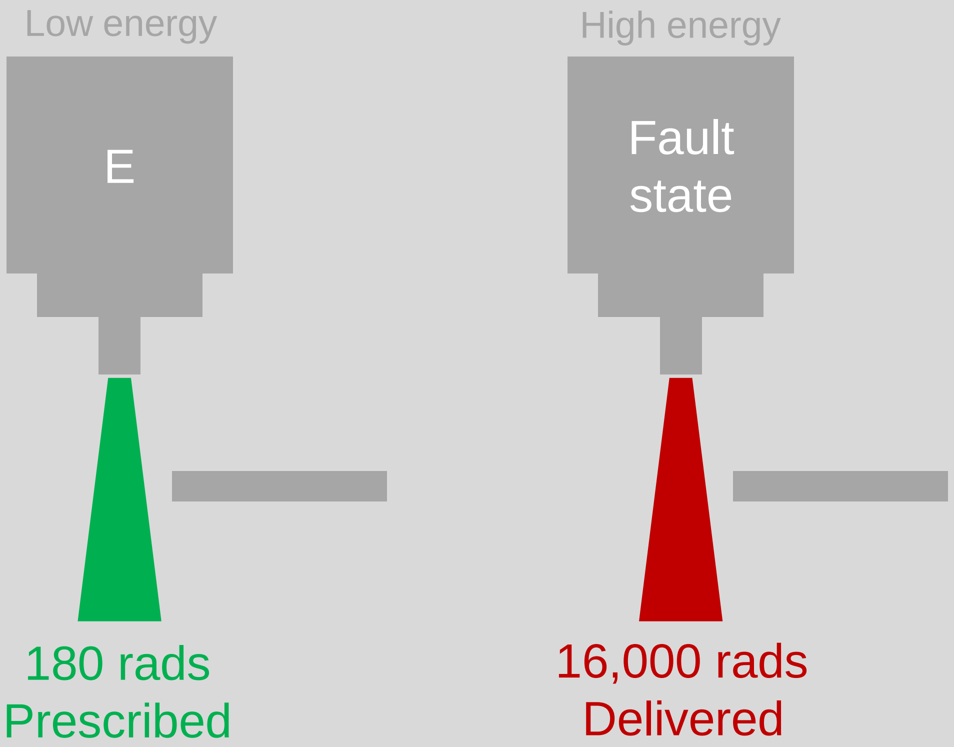
Two modes of operation



The Therac machine had two modes of operation, a low energy electron mode for treating tumours on the skin and a high energy focused beam for treating tumours deep in the body. In the case of the high energy mode a thick shaping plate is required to focus the beam to a small area, reducing its intensity.

In one case in Tyler Texas, a patient was due to receive a low energy electron mode, so the shaping plate was not I place; however, the machine delivered the high energy giving a fatal overdose.

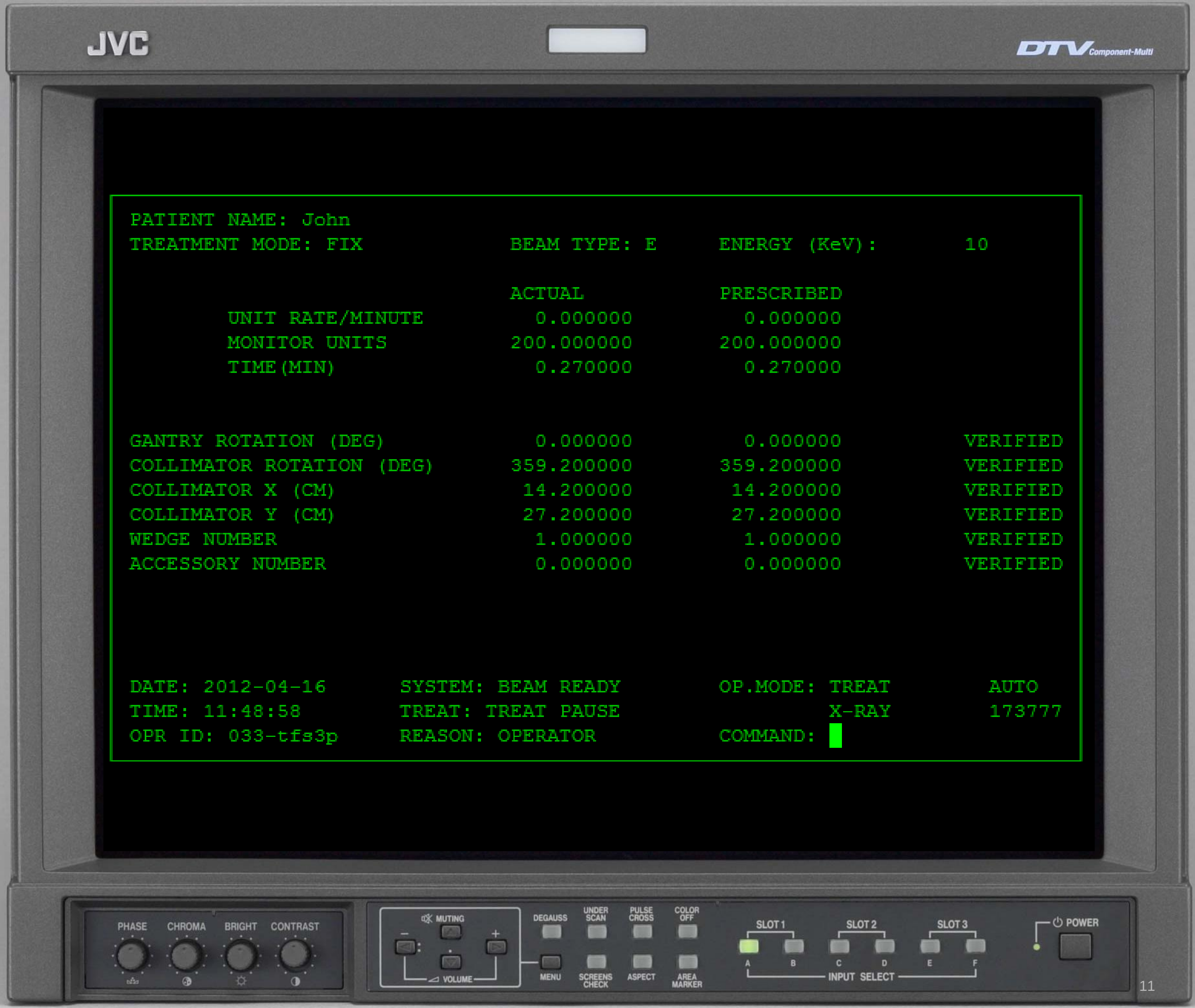
It was an experience operator who had bee using the equipment for two years and delivered over 500 treatments, it was also a straightforward treatment. So what went wrong?



Experienced operator 2 years using the machine and over 500 treatments
Routine electron treatment

Therac 25 interface

This was the user interface, which was fairly typical of its time



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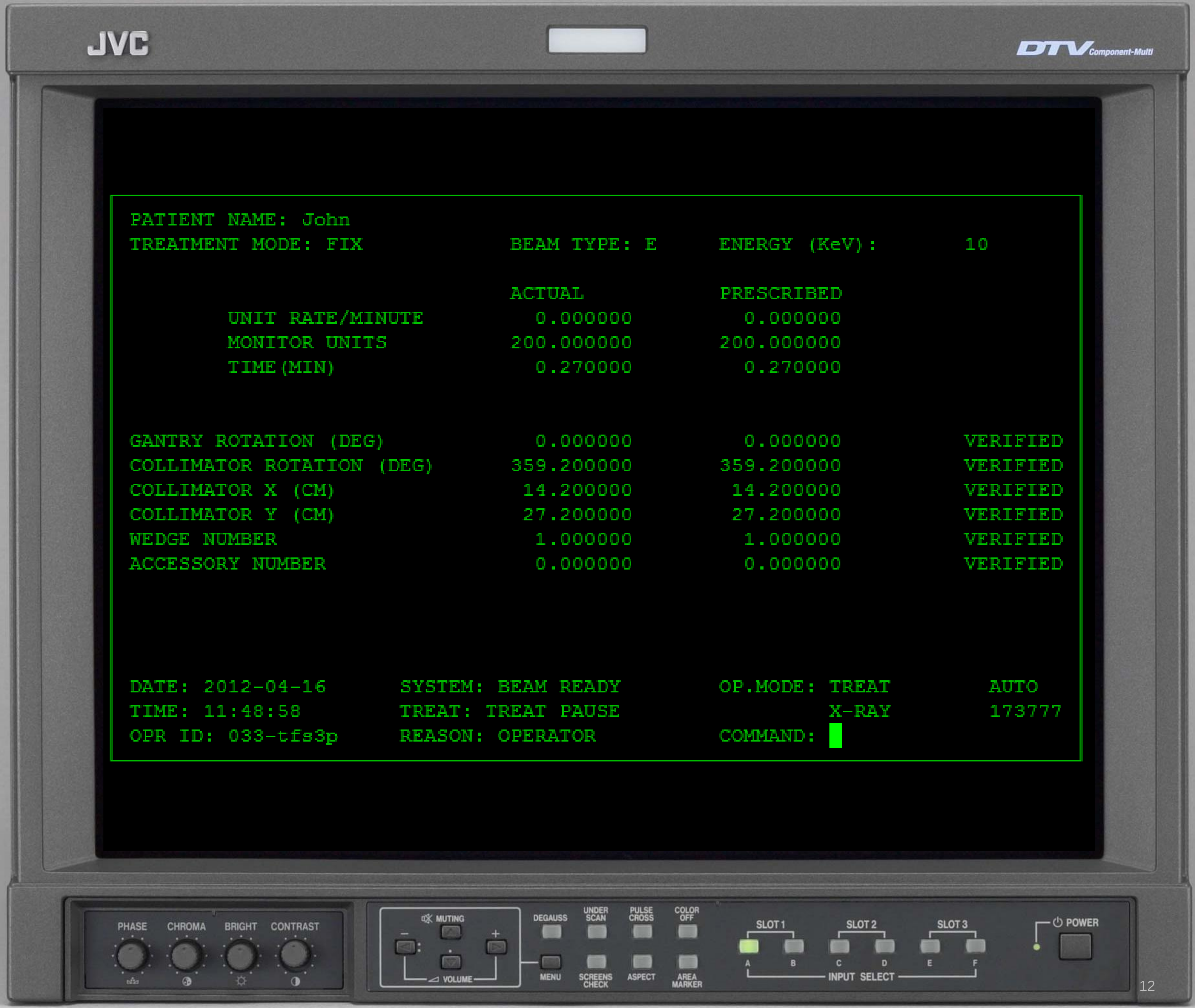
Therac 25 interface

The user entered the patient data as follows:

1. Operator entered prescription data (treatment type and dose).
2. Operator confirmed settings noting that she had mistyped **X** (for X-ray mode) rather than **E** (for an Electron treatment).
3. Operator used the up arrow on the keypad to move the cursor up over the **X** to edit it.
4. Operator typed **E** to overwrite **X** (within 8 seconds of the first entry).
5. Operator typed **B** for beam on.
6. An unfamiliar error was presented on the screen *"Malfunction 54"* however, no information was provided on the details of this error. The operator manual supplied with machine did not explain or address the malfunction codes, nor did it give any indication that these malfunctions could place a patient at risk.
7. As system errors were a relatively common occurrence and routinely accepted, the operator typed **P** for proceed.

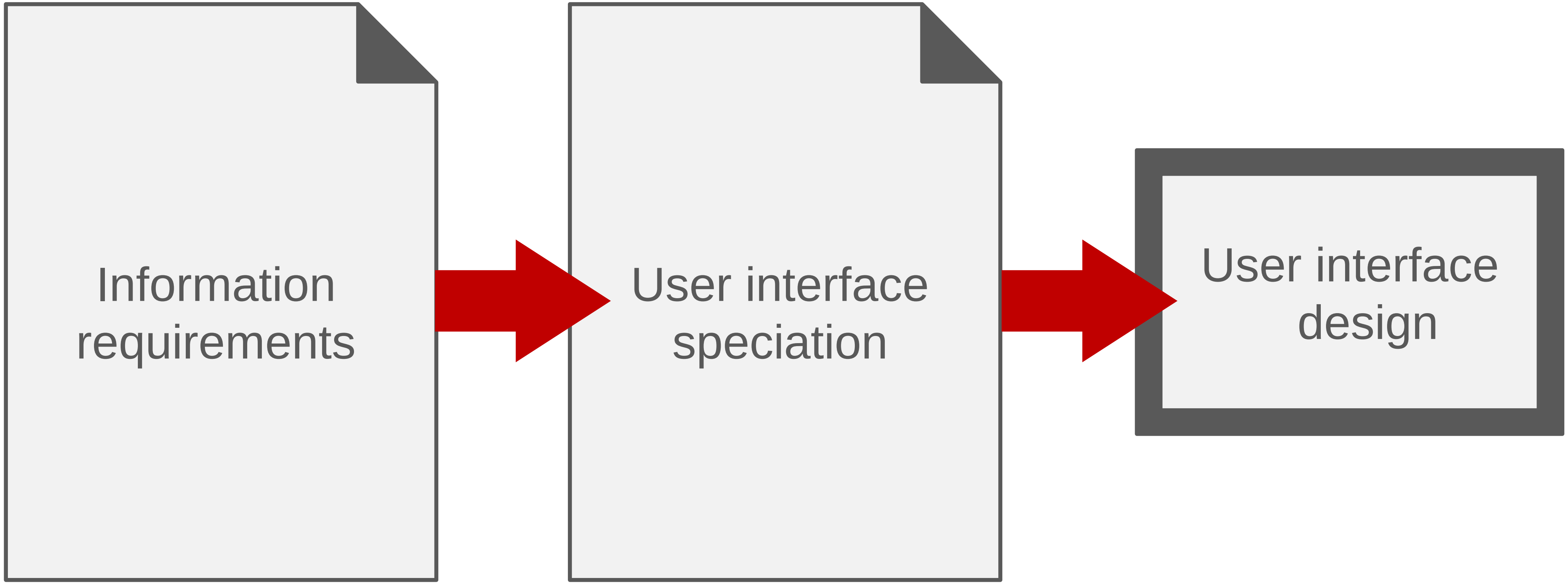
It was later found that that there was a little bit of carryover code in the software, that ignored data entry changes made within 8 seconds, so the machine disregarded the change.

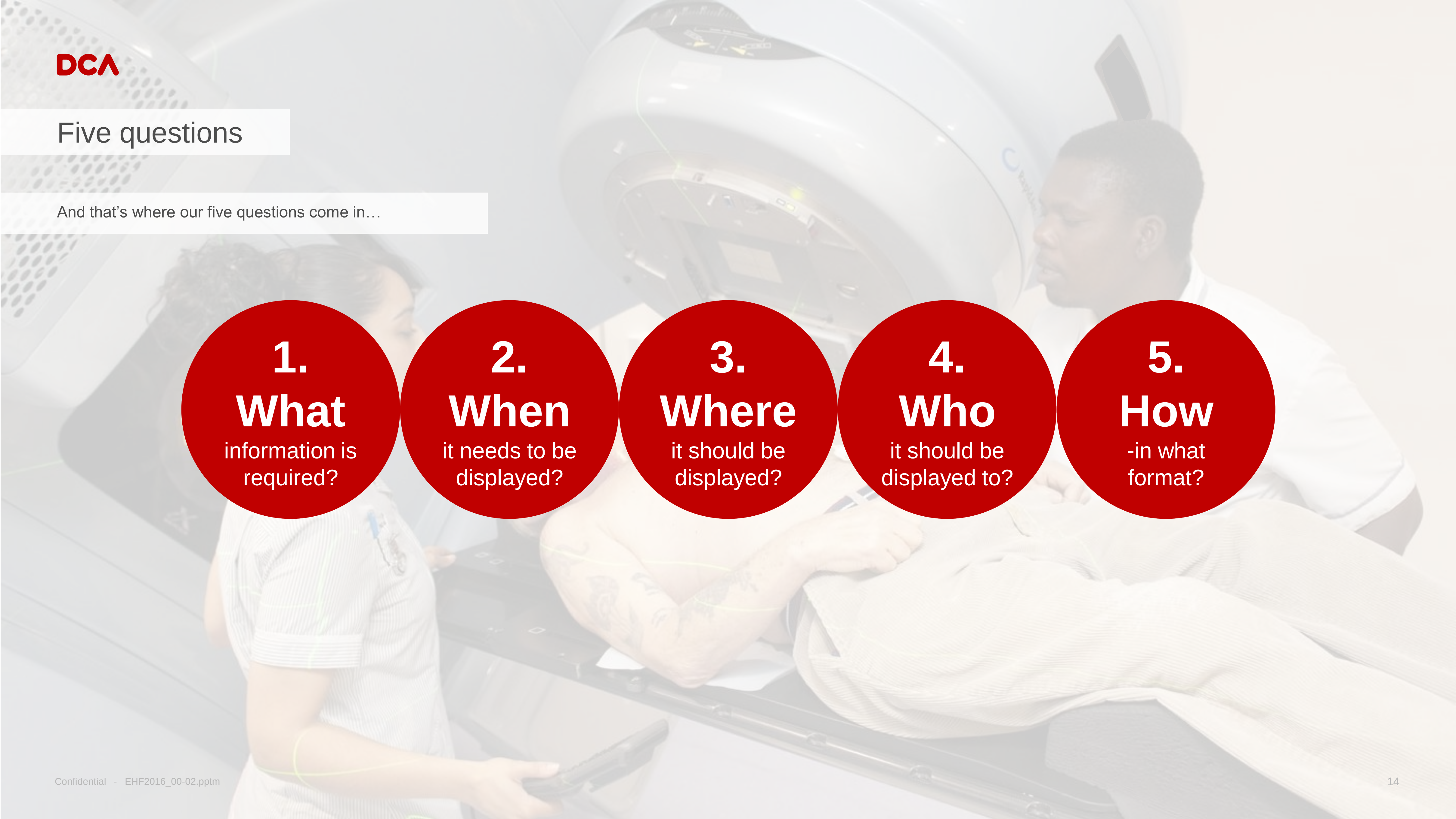
There were no mechanical interlocks in place to check for the shaping plate, thus no defence in place… thus the machine delivered the much more powerful energy dose resulting in an a massive overdose



Hopefully what that example highlights is that it's absolutely critical that we get the design of these interfaces right…

To do that we need a very structured process of considering the information requirements, developing a specification and then designing an interface





Five questions

And that's where our five questions come in…

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?

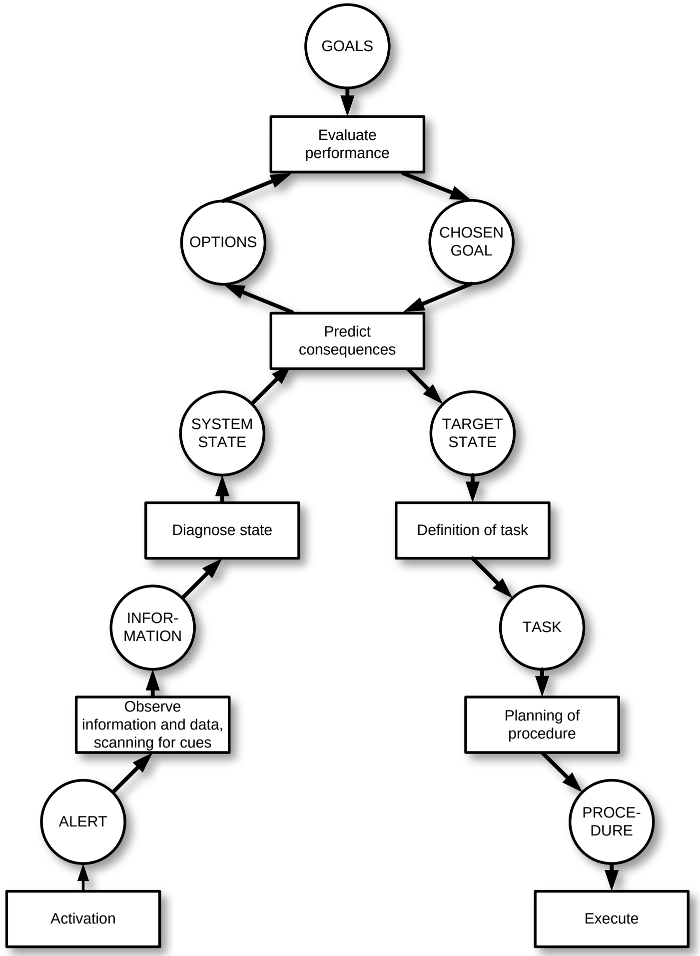
5. How
-in what format?

1. What information is required?

So let's start at the start with what information is required.

As I will hopefully show, Rasmussen's decision ladder is a fantastic way of drawing this out.

For those who haven't seen it, the decision ladder represents a linear decision making process bent in half. It starts in the bottom left with a need to make a decision observations are made information collected, this information is used to diagnose a state, the options are considered, these are then weighed up against the goal, an option is selected a task defined and a procedure developed

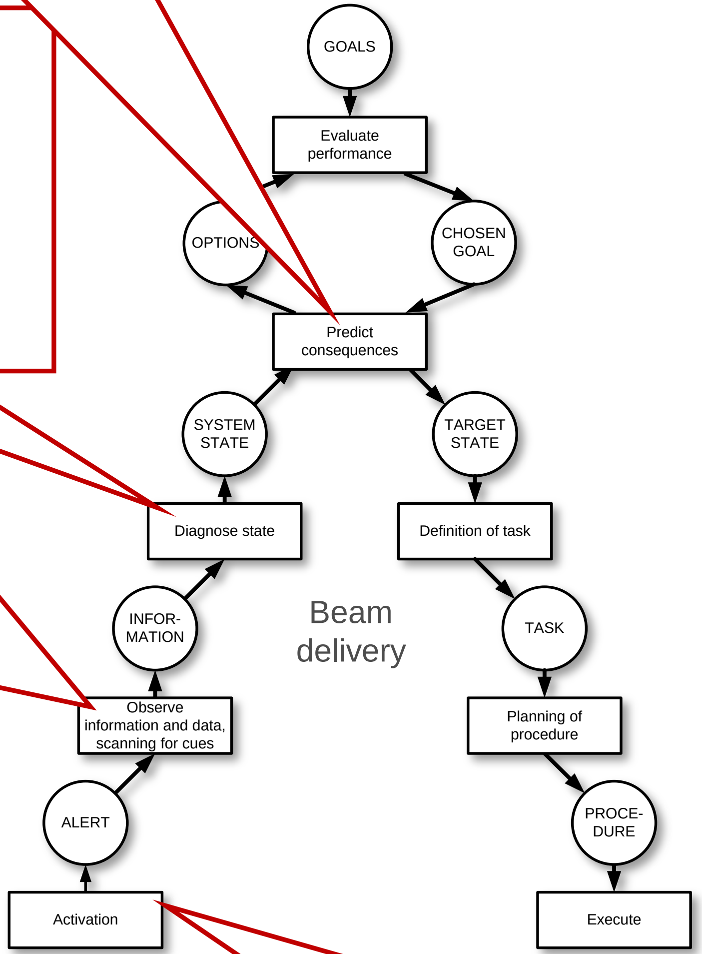


1. What information is required?

Is it possible to pause the treatment?
Is it possible to terminate the treatment?
Is it possible to communicate with the patient?
Is its safe to continue treatment and compensate later?

Is the patient happy to proceed and compliant?
Is the patient positioned correctly in relation to the table?
Is energy correct?

What is the MU being delivered?
What is the prescribed energy?
How is the patient positioned (posture)?
How should the patient be positioned (posture)?



Planned process to monitor
Communication from patient

We can take an example during the beam delivery.

If you interview operators with the model in front of them they will tend to describe it like this. The activation is that the operator should be monitoring the process, the patient may also call out.

At this stage the main information elements are from the screen displaying the dose being delivered and from the CCTV showing the position of the patient.

These elements are then fused to determine if the patient is okay, in the right position and getting the right dose.

The options are fairly limited, pause or terminate the treatment, talk to the patient or keep going

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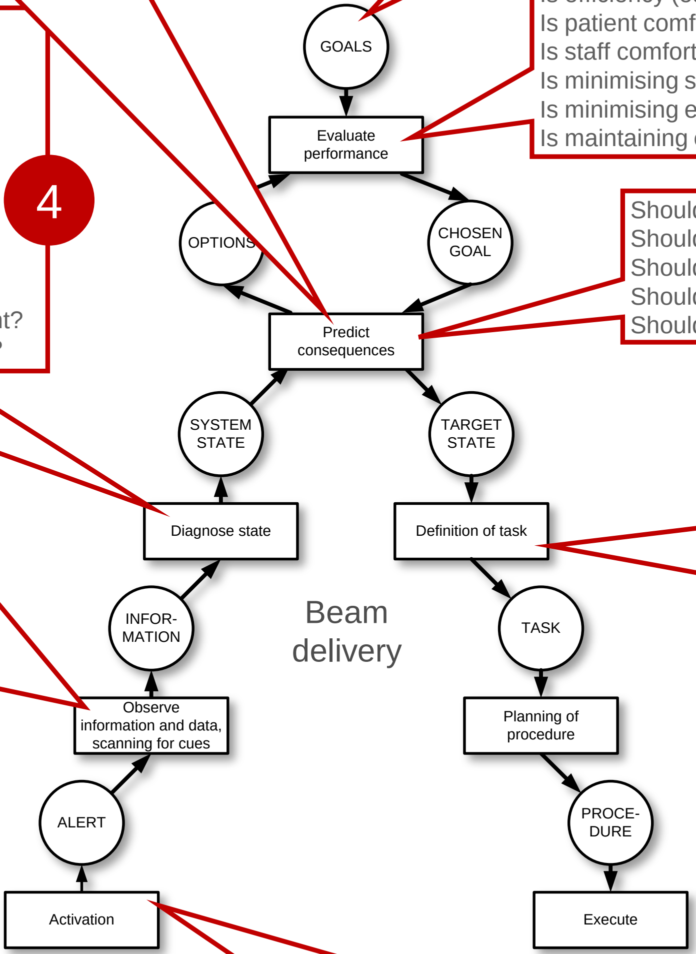

1

Deliver treatment *(considering efficacy, efficiency, comfort, side effects, errors & equipment availability)*

2

- Planned process to monitor
- Unexpected alarm (auditory)
- Unexpected alarm (visual)
- Communication from patient
- Communication from control room

3

- What is the MU being delivered?
- What is the gantry angle on the software system?
- What is the gantry angle on CCTV?
- What auxiliary equipment is in the room?
- Where is the patient table?
- What is the beam shape?
- What is the cancer type?
- What is the treatment?
- How deep is the tumour?
- What is the prescribed energy?
- How is the patient positioned (posture)?
- How should the patient be positioned (posture)?
- Is the patient making a noise?
- Does the patient have physical needs?
- Does the patient have mental needs?
- Is the patient comfortable?
- Is the patient relaxed?
- Is the patient cooperative?
- Is the machine making a noise?

4

- Is the patient happy to proceed and compliant?
- Is the room clear bar the patient?
- Are the machines communicating correctly?
- Do the plan and diagnosis match?
- Is the gantry in the correct position?
- Is the patient positioned correctly in relation to the table?
- Is patient correctly aligned to machine?
- Is the machine delivering the dose it says it is?
- Is energy correct?
- Can equipment be moved without a collision?
- Does the patient require repositioning during the treatment?
- Does the patient require setup changes during treatment?

5

- Is it possible to pause the treatment?
- Is it possible to terminate the treatment?
- Is it possible to communicate with the patient?
- Is it safe to request a second opinion?
- Is its safe to continue treatment and compensate later?

6

- Is effectiveness of treatment (irradiate tumour) the chosen priority?
- Is efficiency (equipment usage time) the chosen priority?
- Is patient comfort the chosen priority?
- Is staff comfort and wellbeing the chosen priority?
- Is minimising side effects the chosen priority?
- Is minimising errors the chosen priority?
- Is maintaining equipment availability the chosen priority?

7

- Should the treatment be paused?
- Should the treatment be terminated?
- Should the patient be communicate with?
- Should second opinion be sought?
- Should the treatment continued with future compensation?

8

- Hit the pause button
- Hit the terminate button
- Hit emergency stop button on wall
- Open door to treatment room (activating interlock)
- Press intercom button and speak
- Call out for assistance (local area)
- Phone for assistance

The next thing to do then is to go around the loop again, this time asking the question are there any other alerts, information elements and system states could help you, what if some information was missing what other information might you use…

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2. When

it needs to be displayed?

We started by thinking about all the information elements that could be used, but up until this point this should all be independent of when, where, and who needs access.

The next step is to go back through that long list of alerts, information elements, and system states and to start to decide when that information is needed through the process.

A small sample is shown below.

Straight away we can see that some aspects are persistent information sources, its useful to know the patients name at all times, whereas aspects such as their size and weight are only really critical when moving them.

ID	Description	1. Patient check in	2. Machine prep	3. Patient set up	4. Machine set up	5. Deliver radiation	6. Unload patient	7. Clean machine
AL01	Patient appears agitated							
AL02	Unexpected alarm (auditory)							
AL03	Communication from patient							
IE01	What is the name of the patient							
IE02	What is the weight of the patient							
IE03	What is the size of the patient							
IE04	Does the patient have physical needs							
IE05	What is the MU being delivered							
IE06	What is the cancer type							
IE07	Does the patient have other appointments							
SS01	Is the patient happy to proceed							

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We can take a similar approach to determining where information should be displayed, again with a limited sample.

Some aspects such as the size and weight of the patient are only really important in the physical environment, other information best lives in the digital world

3. Where it should be displayed?

ID	Description	Physical environment		Machine feedback		Documents (physical or digital)			Comms	
		Control room	Treatment rooms	Control room screens	Treatment room screens	Patient information	Patient description	Schedule	Patient	Staff
AL01	Patient appears agitated									
AL02	Unexpected alarm (auditory)									
AL03	Communication from patient									
IE01	What is the name of the patient									
IE02	What is the weight of the patient									
IE03	What is the size of the patient									
IE04	Does the patient have physical needs									
IE05	What is the MU being delivered									
IE06	What is the cancer type									
IE07	Does the patient have other appointments									
SS01	Is the patient happy to proceed									

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4. Who it should be displayed to?

The next step is who needs access to the information, as expected the radiotherapists are central to this but what about others in the system? What kind of information should be accessible to them?

ID	Description	Reception staff	Radio-therapists	Oncologists	Dosimetrists	Maintenance staff	Patients	Porters
AL01	Patient appears agitated							
AL02	Unexpected alarm (auditory)							
AL03	Communication from patient							
IE01	What is the name of the patient							
IE02	What is the weight of the patient							
IE03	What is the size of the patient							
IE04	Does the patient have physical needs							
IE05	What is the MU being delivered							
IE06	What is the cancer type							
IE07	Does the patient have other appointments							
SS01	Is the patient happy to proceed							

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Finally we can think about how information is presented, we can think of this in terms of the digital screens but also the wider system. what should be displayed on the machine itself, what should be displaying in the control room, what should be displayed on the patients wrist ban, on their paper notes, what should be written on their accessories.

5. How

-in what format?

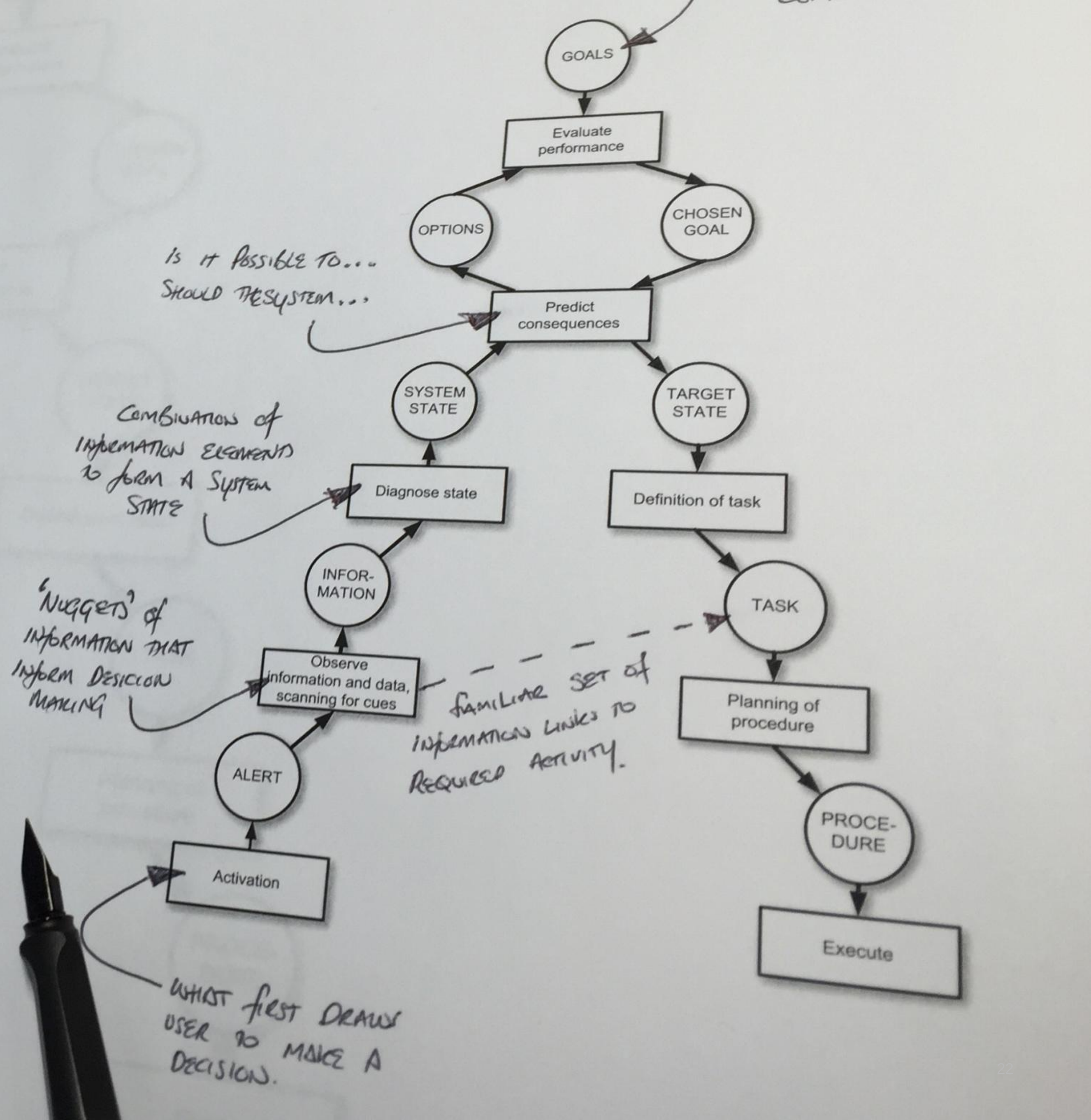
ID	Description	Format
AL01	Patient appears agitated	High quality image and videos of patient
AL02	Unexpected alarm (auditory)	Unique sounding alarm louder than background
AL03	Communication from patient	High quality audio
IE01	What is the name of the patient	Text
IE02	What is the weight of the patient	Numerical with units
IE03	What is the size of the patient	Numerical with units
IE04	Does the patient have physical needs	Text field
IE05	What is the MU being delivered	Numerical with units
IE06	What is the cancer type	Text field / map of body
IE07	Does the patient have multiple appointments	Schedule
SS01	Is the patient happy to proceed	High quality image of patient

Conclusions

The approach provides an explicit description of:

- What information is required? – this is explicitly captured in the decision ladder models
- When it needs to be displayed? – this is captured in the summary table (each information element is coded to indicate which situation or task it is relevant to)
- Where it should be displayed? – this is coded in the matrix
- Whom it should be displayed to? – the matrix can be coded to indicate which actors should receive each of the information element
- How, in what format? – by determining the data type (e.g. between limits, binary, multi-state, etc.) it is possible to determine the best solution for each information element

So hopefully what this presentation has shown is that it's really critical that we get this right, really. Very subtle changes to the way information is managed and presented can have profound impacts on safety, efficacy and efficiency of the system. Using this structured approach we can capture each of the bits of information we might need and start to drill down into the design of them, albeit the equipment, the digital displays or even the wrist bands.



Questions

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