Requirements Definition

Design Process

	Design Step		Action	Outcome
Initial Problem	Problem Definition		Surveys, Case Studies, Action Research	Explicit Problem Defenition
	Requirement Definition		Surveys, Case Studies, Action Research	Quantitative & Qualitative Requirements
	Design & Development	Development Design Candidates	Creative Methods, Innovation	Mockups / Rapid Prototyping
		Select the Best Design (Solution)	Optimization	Primary / Secondary Design
		Construct a Prototype	Machining / Rapid Prototyping	Artifact / Fully functional System
	Demonstration		Experiments, Case Studies / Action Research	Demonstrated Prototype (Basic Functionality)
	Evaluate		Experiments, Case Studies / Action Research	Evaluated Prototype (Meeting Requirements)
	Reporting		Summary of the Design Process / Lesson Learned	Final Report
	Redesign			

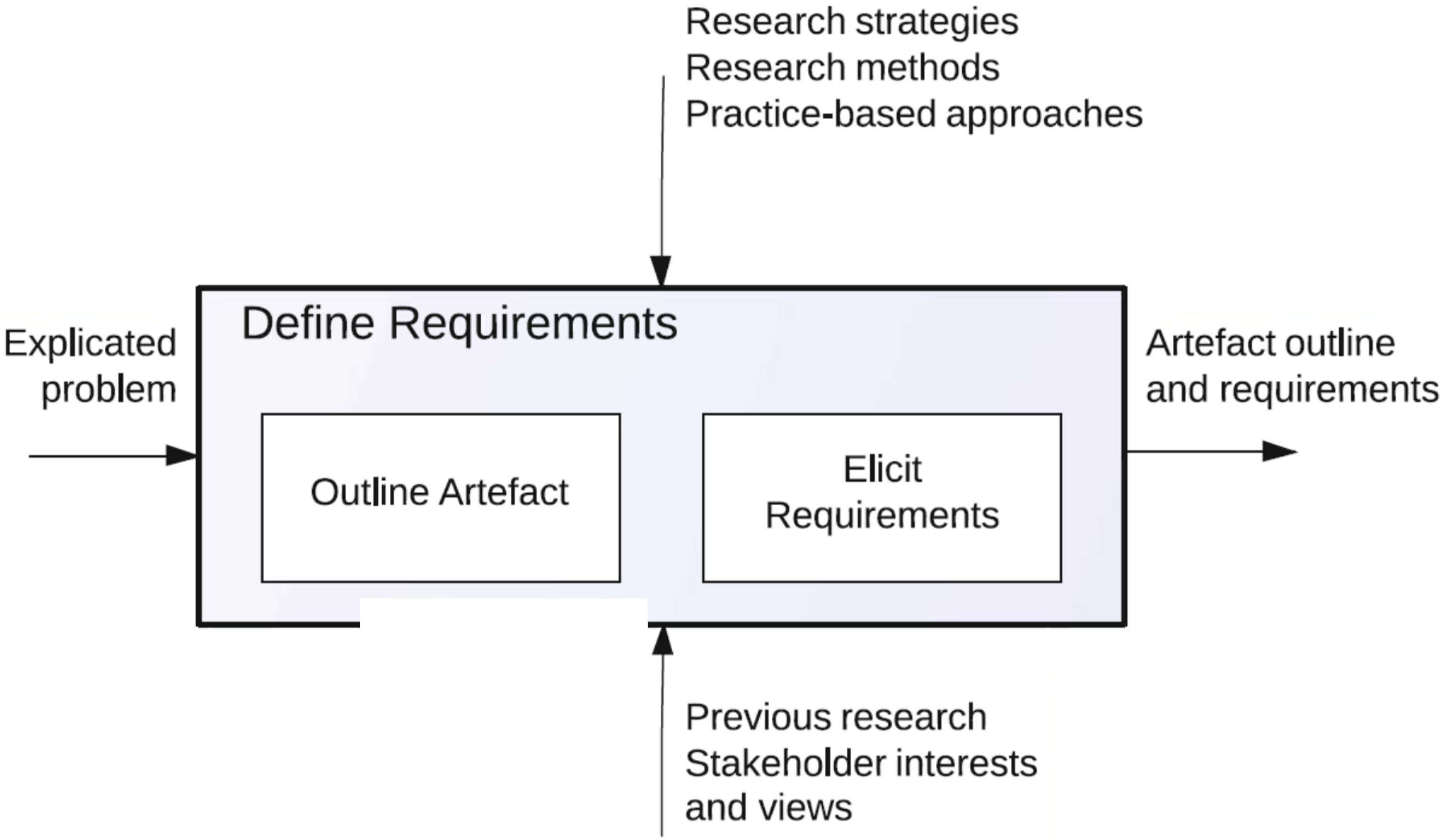
Requirements - Definition

What type of artefact can be a solution for the explicated problem?

Which requirements of this artefact are important for the stakeholders?

- Requirement (Definition) - A requirement is a property of an artefact that is
  - Deemed as desirable by stakeholders
  - Used for guiding the design and development of the artefact.

Requirements – Definition



Research strategies
Research methods
Practice-based approaches

Explicated problem

Define Requirements

Outline Artefact

Elicit Requirements

Artefact outline and requirements

Previous research
Stakeholder interests and views

Artefacts as Solutions to Problems in Practices

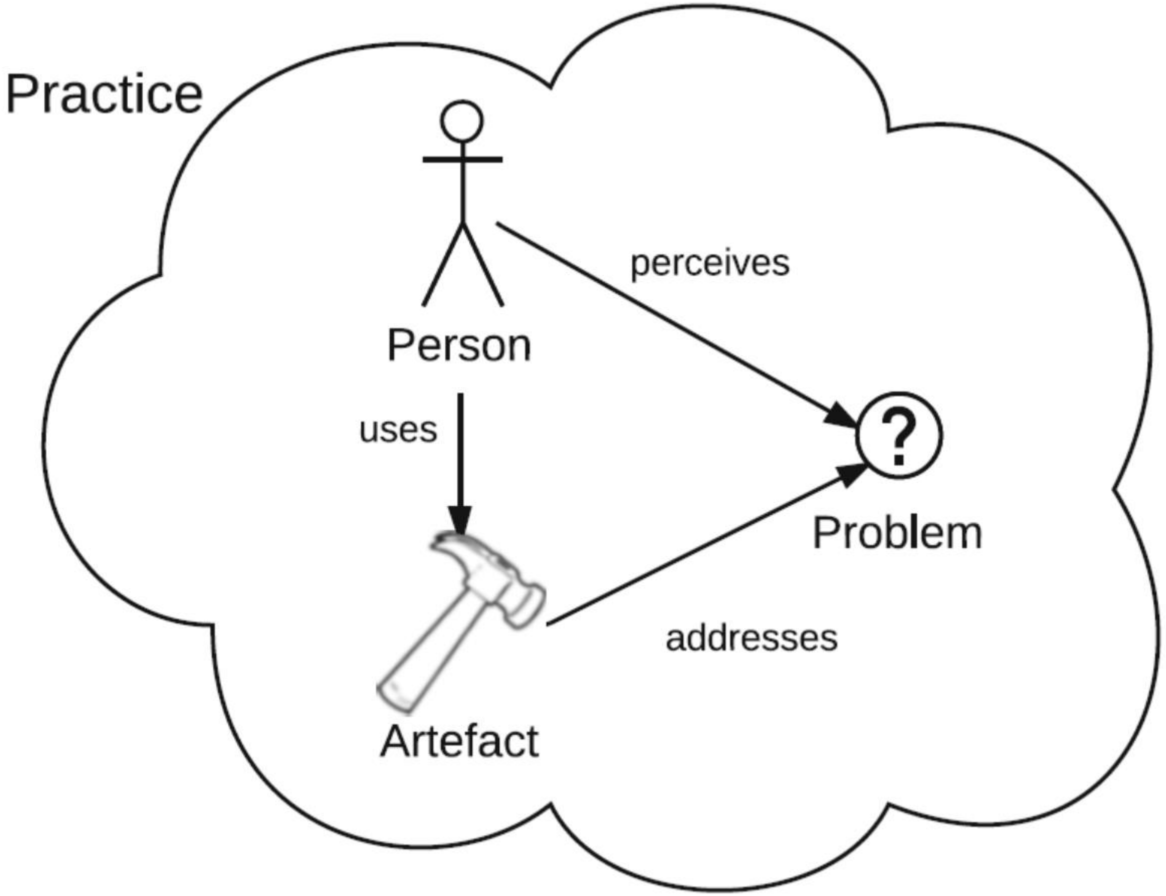
- Reactions to Problems
- Extreme Case 1: Accept the problem as a fact of life (stoic attitude) –
  - Example: Cancer
- Extreme Case 2: Abandon the practice
  - Example: Bloodletting, which was an established practice in medicine for centuries but ceased when evidence mounted regarding its adverse health effects
- Common - Try to find some, often partial, solution to it.

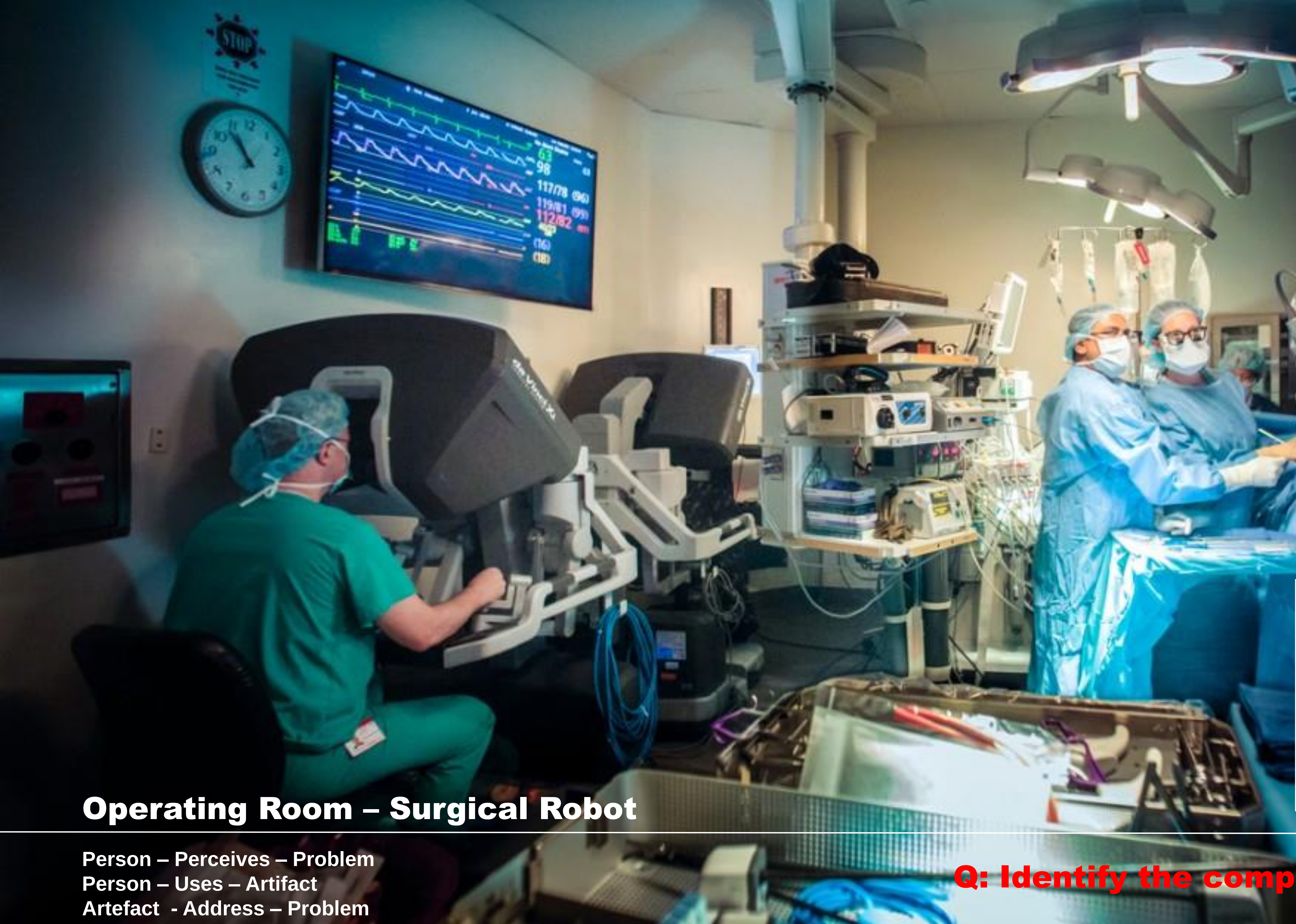
Artifact - Definition

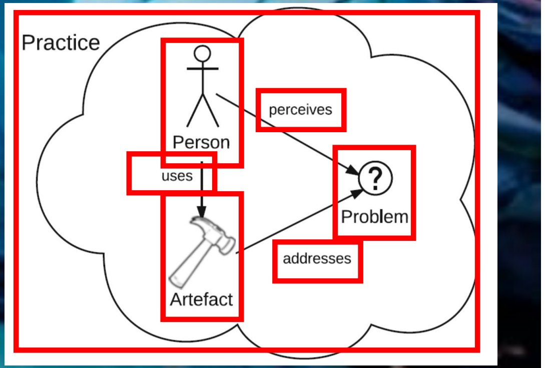
- **Artefact (Definition)** - An object made by humans with the intention that it be used to address a practical problem.

- **Type of Artifacts**
  - Physical Objects – Examples: hammers, cars, and hip joint
  - Plans (drawings or blueprints) – Example: architect's plan for a building
  - Methods, Guidelines, Algorithms, Processes - Example: A method for designing databases, logic programs, software architectures, information models

Artifact – Definition



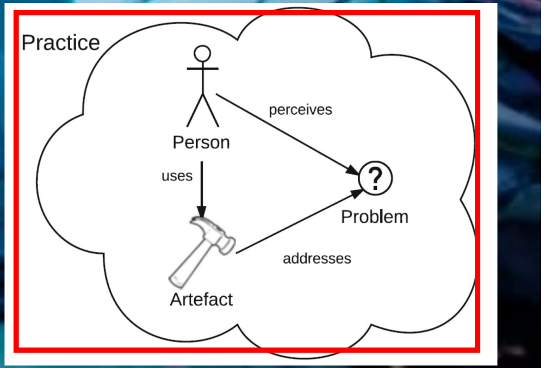




Operating Room – Surgical Robot

Person – Perceives – Problem
Person – Uses – Artifact
Artefact - Address – Problem

Q: Identify the component of the model



Operating Room – Surgical Robot

Person – Perceives – Problem
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Q: What is the practice

Operating Room – Surgical Robot

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Q: What is the practice

Operating Room – Surgical Robot

Person – Perceives – Problem
Person – Uses – Artifact
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Q: What is the problem

Operating Room – Surgical Robot

Person – Perceives – Problem
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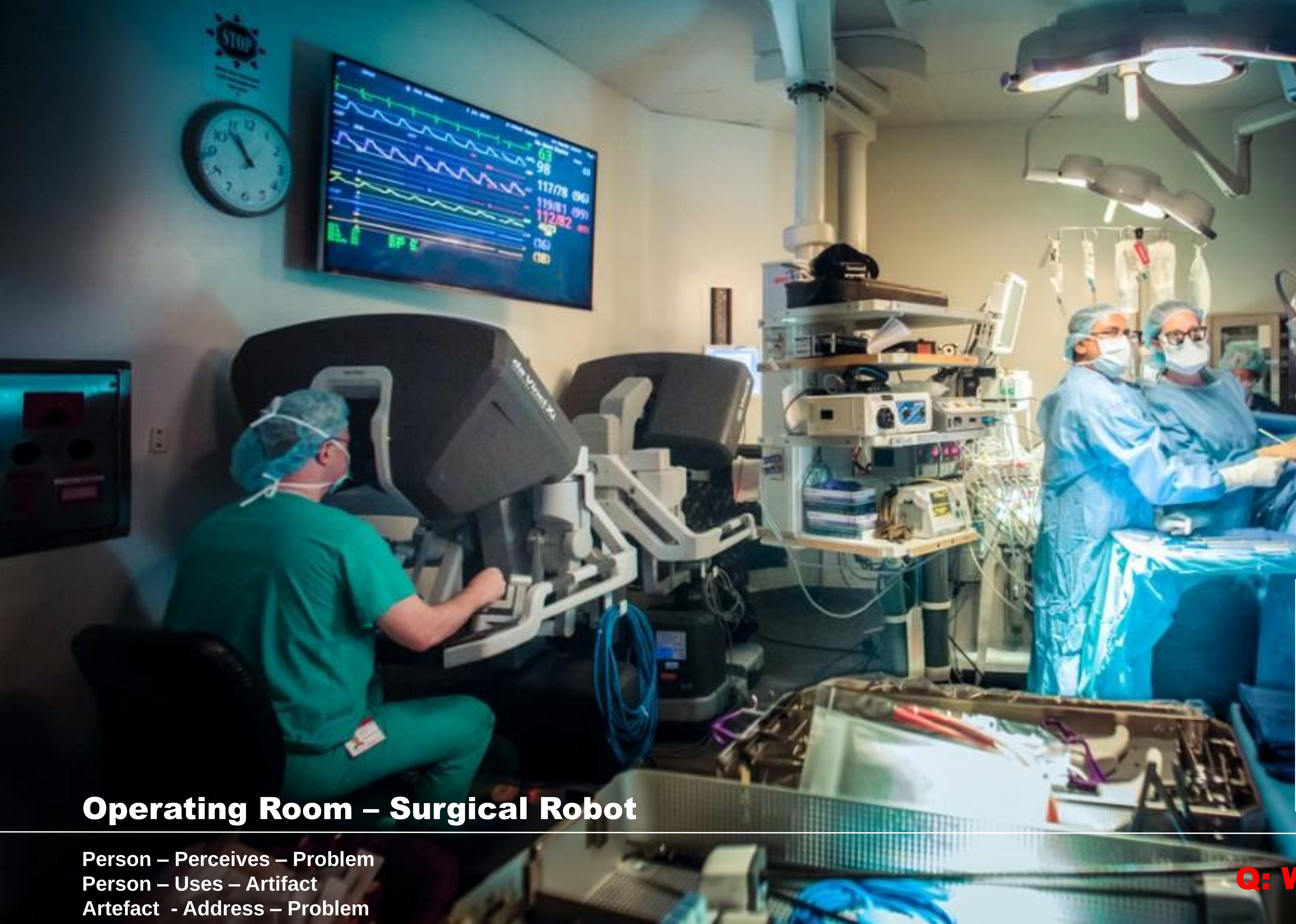
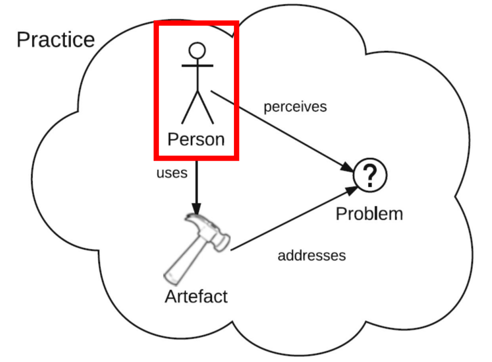
Q: What is the problem





Operating Room – Surgical Robot

Person – Perceives – Problem
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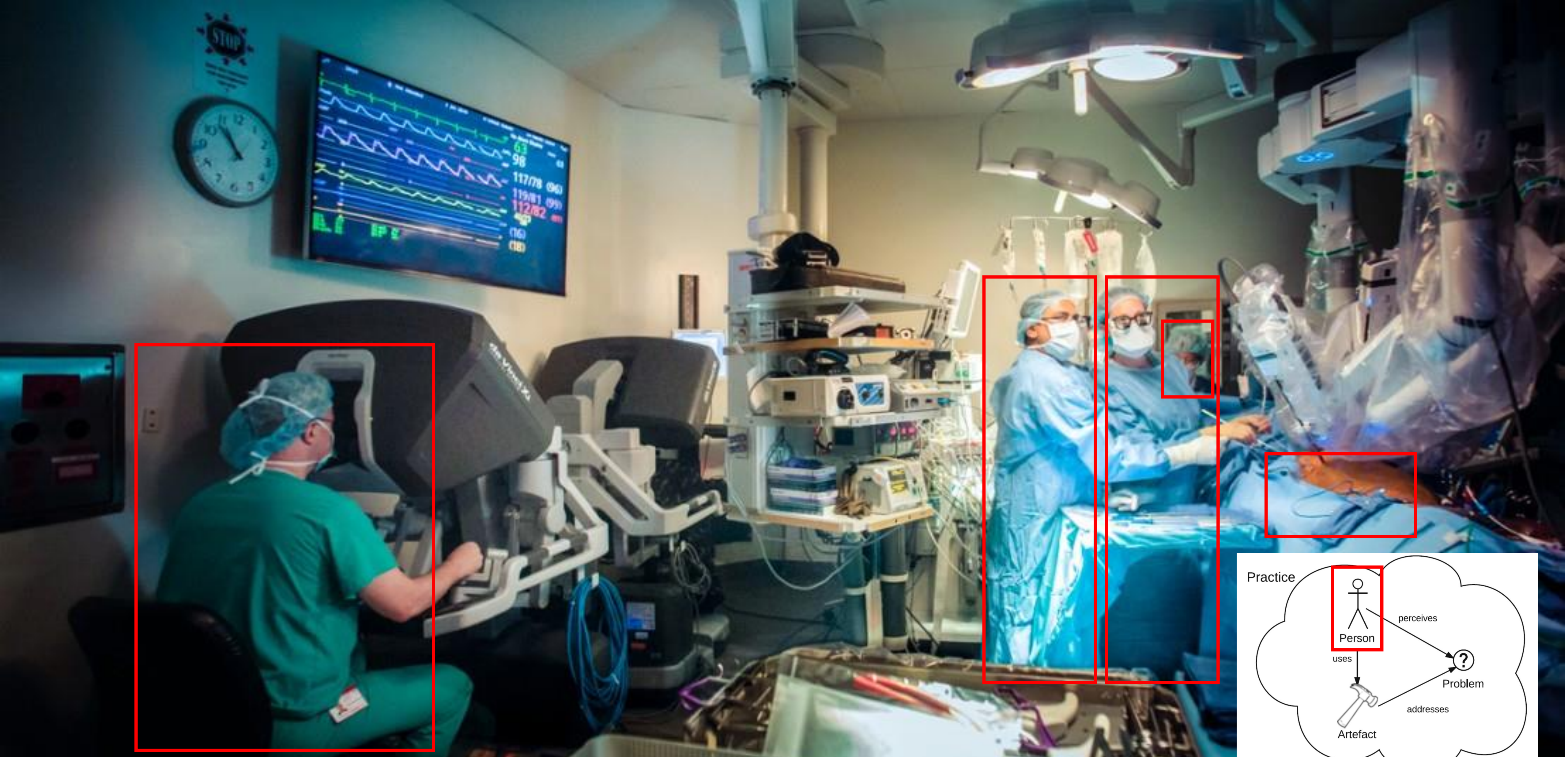
Q: Who are the People



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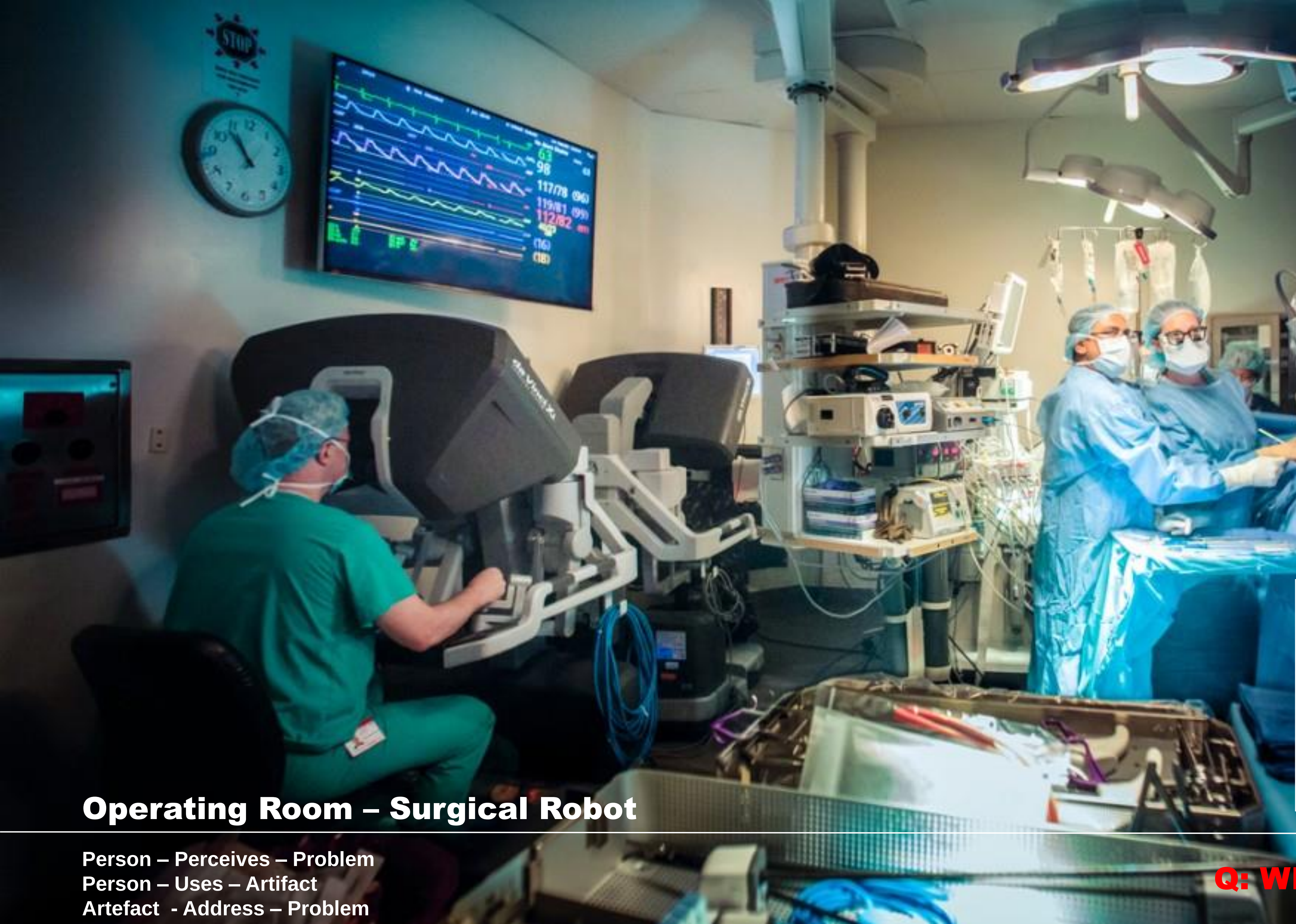
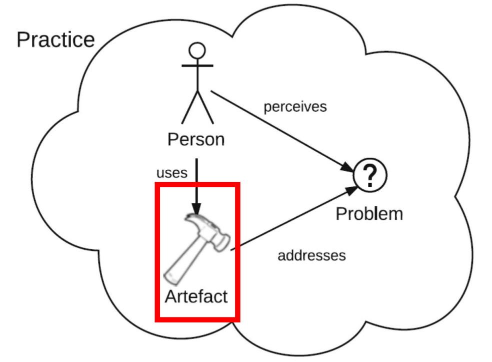
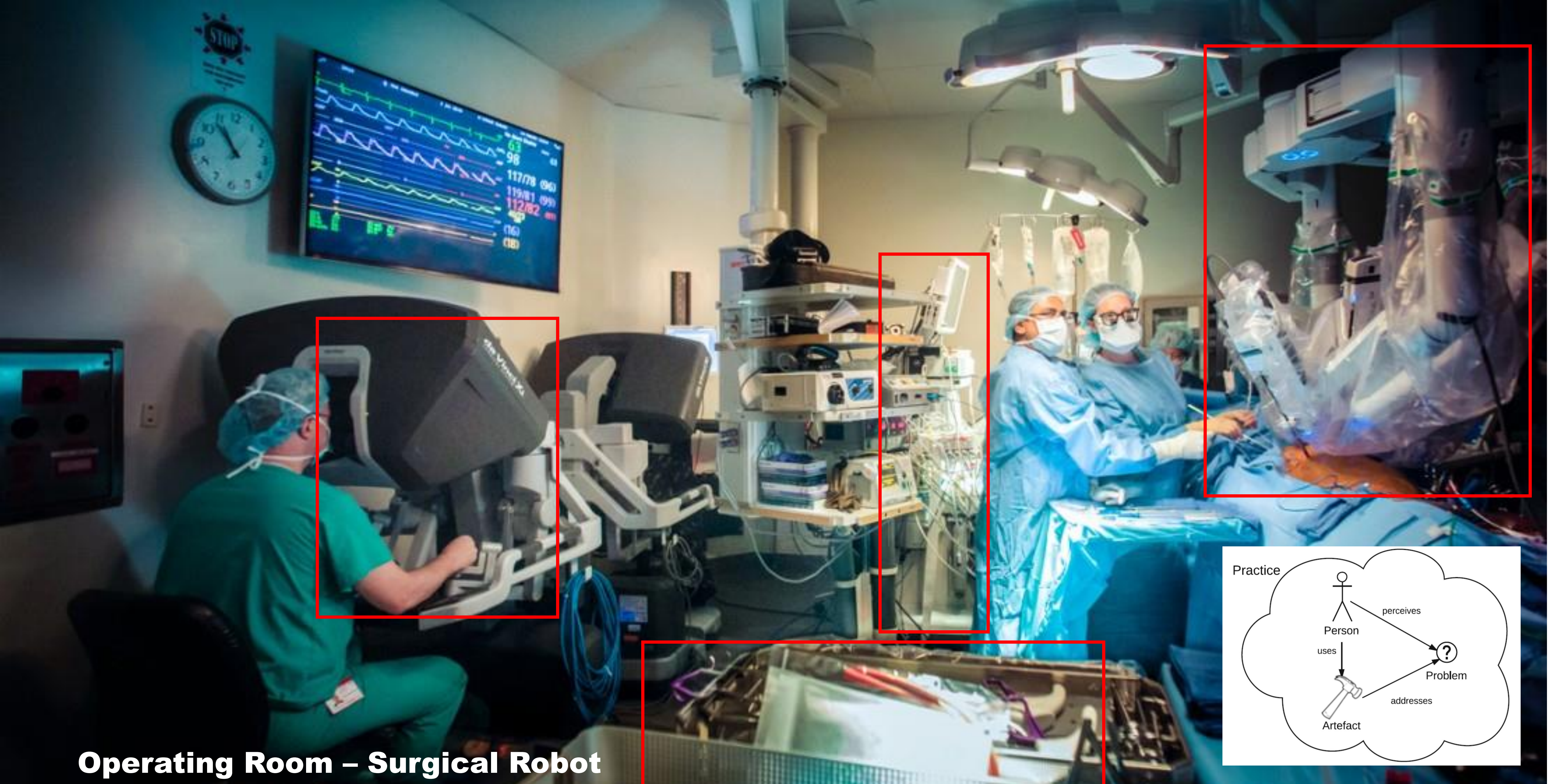




Operating Room – Surgical Robot

Person – Perceives – Problem
Person – Uses – Artifact
Artefact - Address – Problem

Q: What is the Artifacts



Operating Room – Surgical Robot

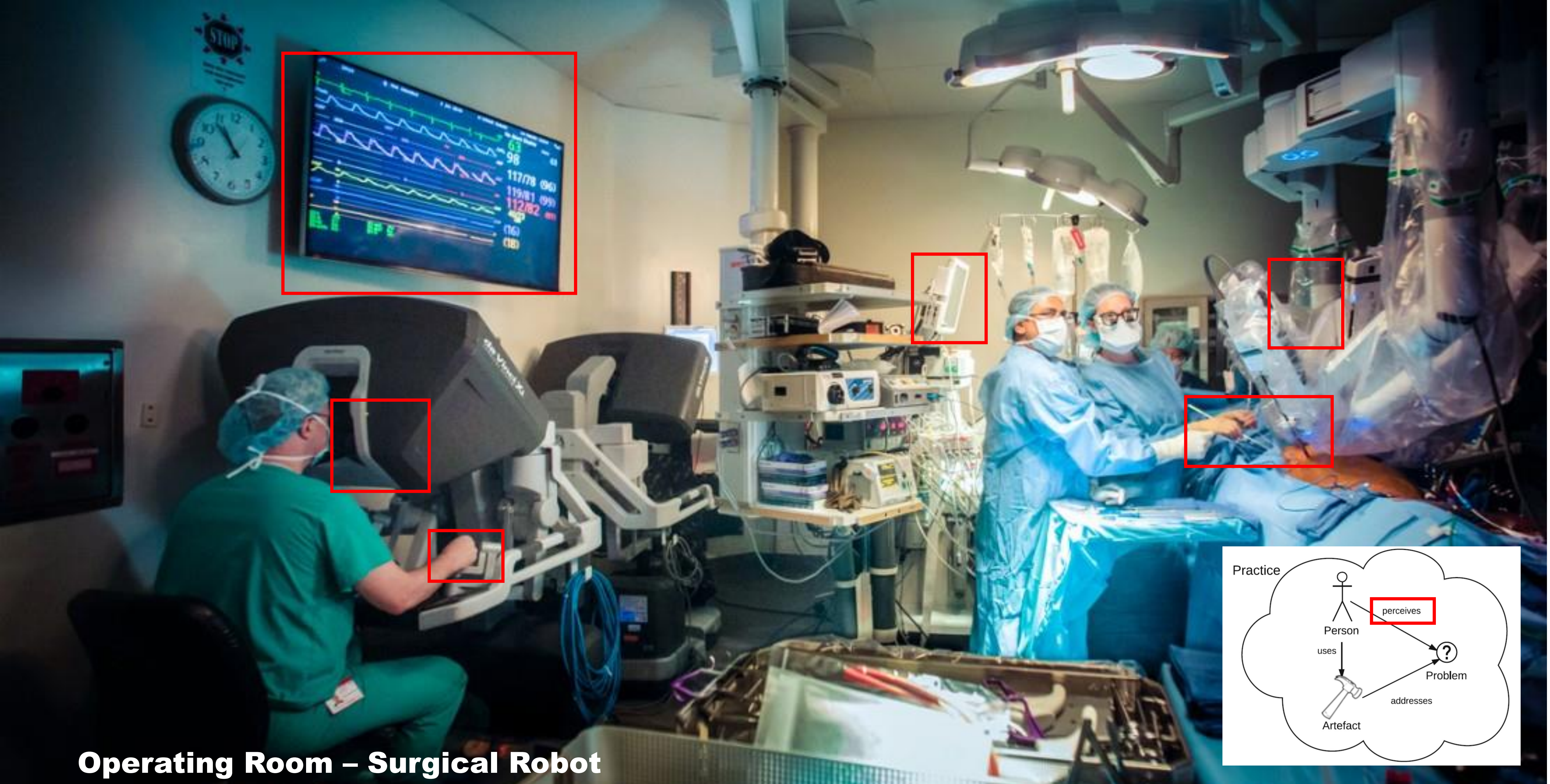
Person – Perceives – Problem
Person – Uses – Artifact
Artefact - Address – Problem

Q: What is the Artifacts

Operating Room – Surgical Robot

Person – Perceives – Problem
Person – Uses – Artifact
Artefact - Address – Problem

Q: How is the problem perceived by the person



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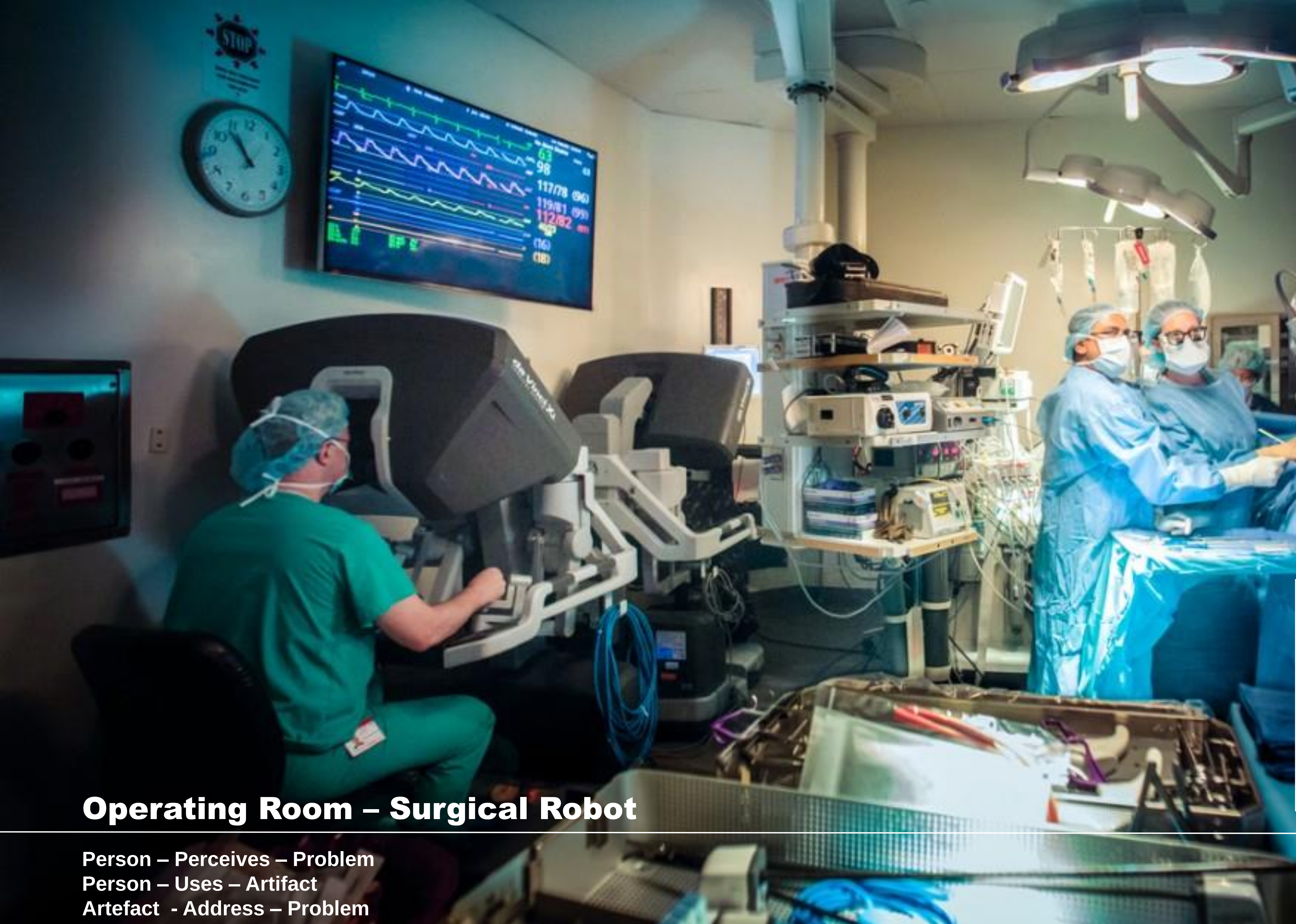

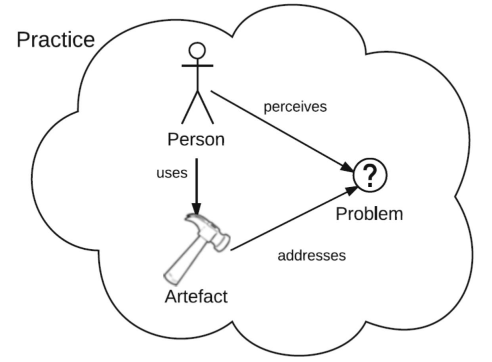

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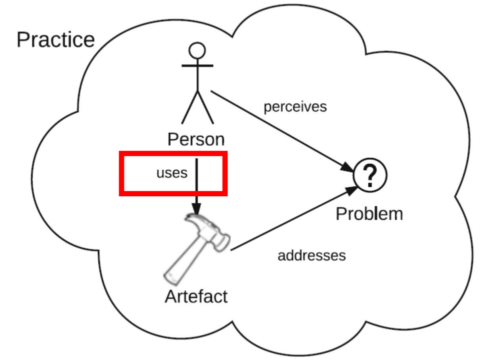
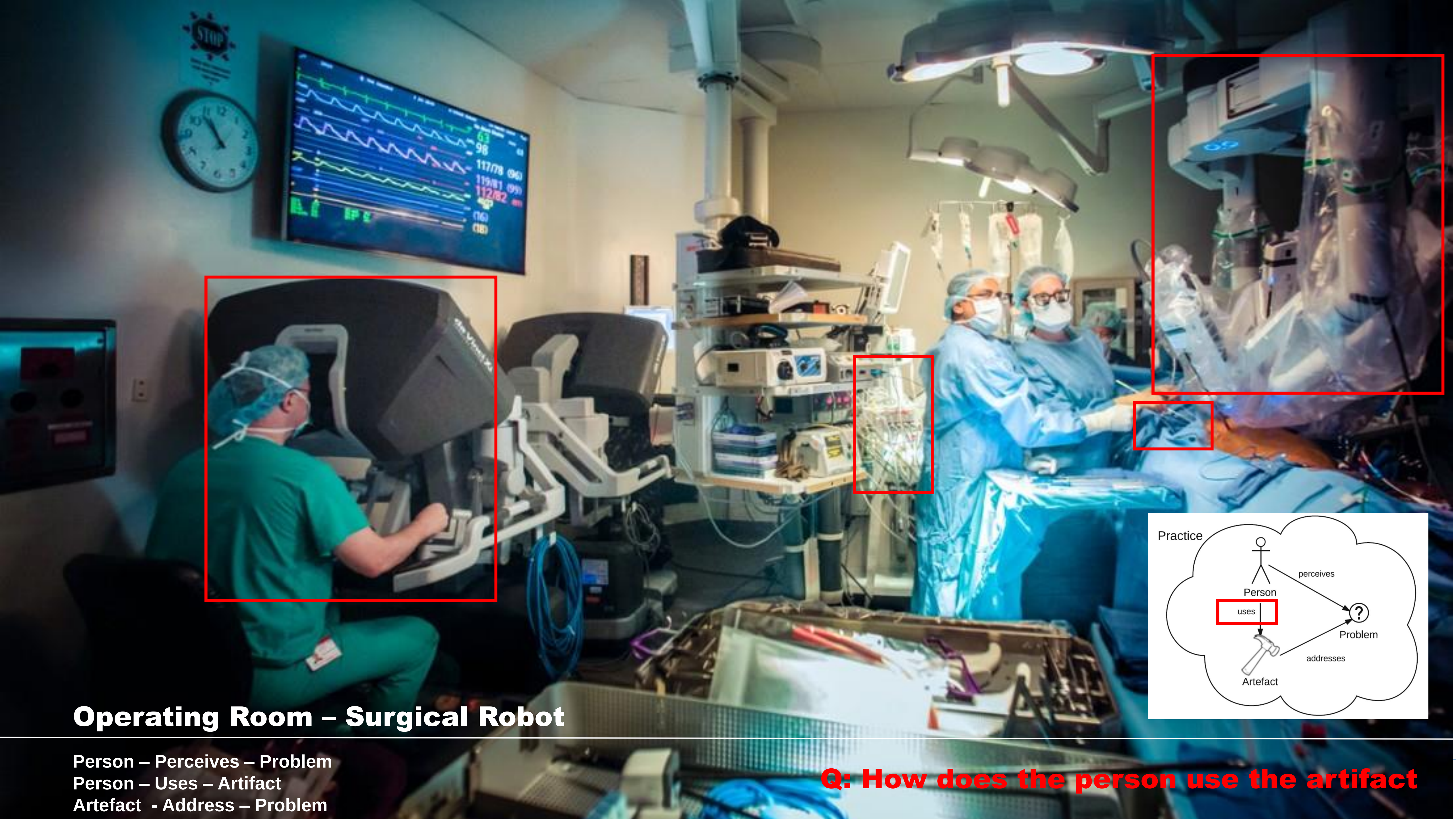


Operating Room – Surgical Robot

Person – Perceives – Problem
Person – Uses – Artifact
Artefact - Address – Problem

Q: How does the person use the artifact



Operating Room – Surgical Robot

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Artefact - Address – Problem

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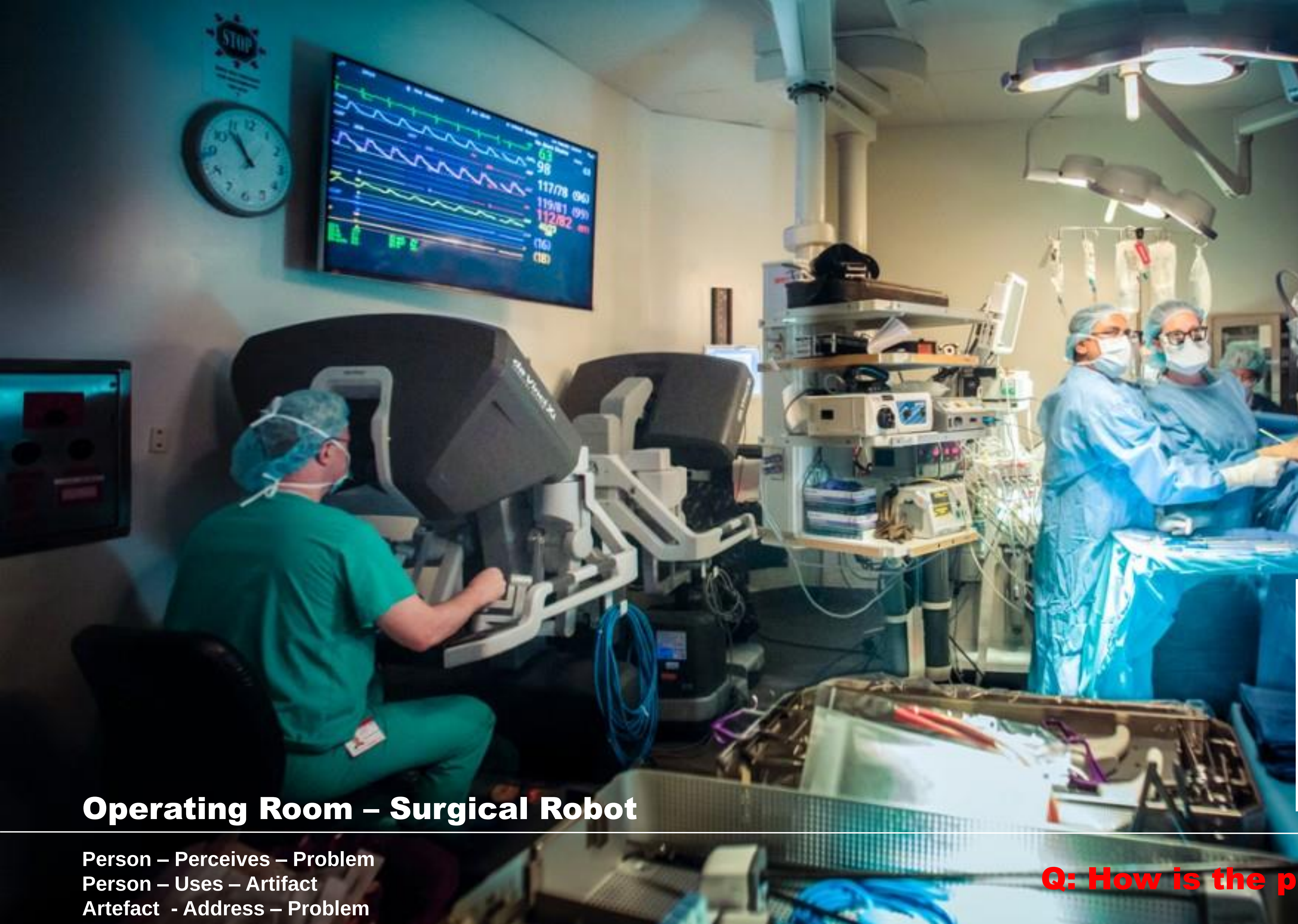

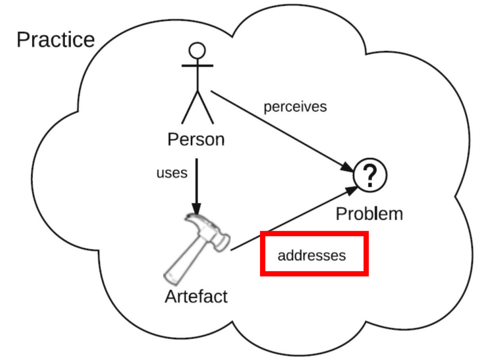

Operating Room – Surgical Robot

Person – Perceives – Problem
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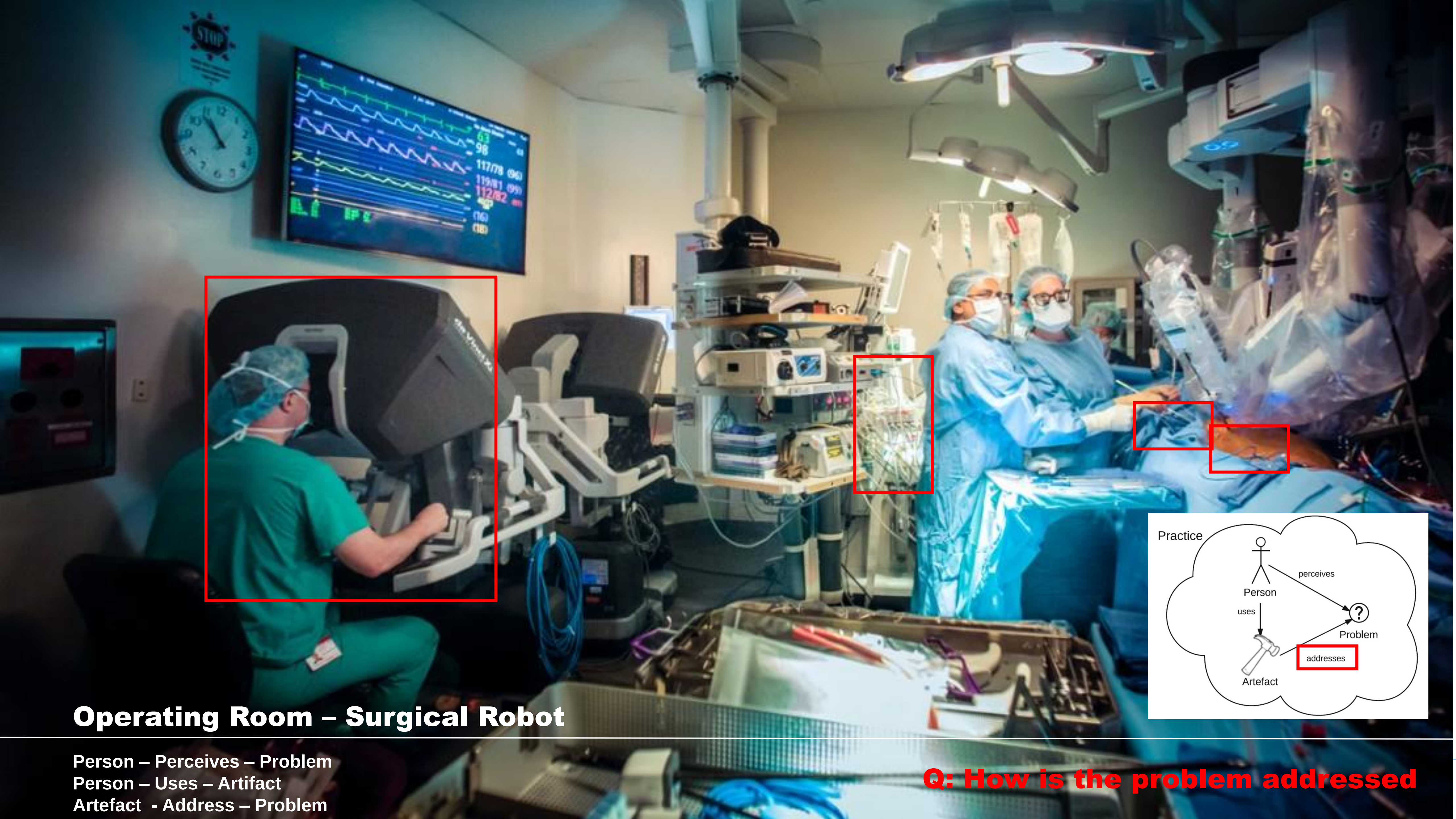
Q: How is the problem addressed



Operating Room – Surgical Robot

Person – Perceives – Problem
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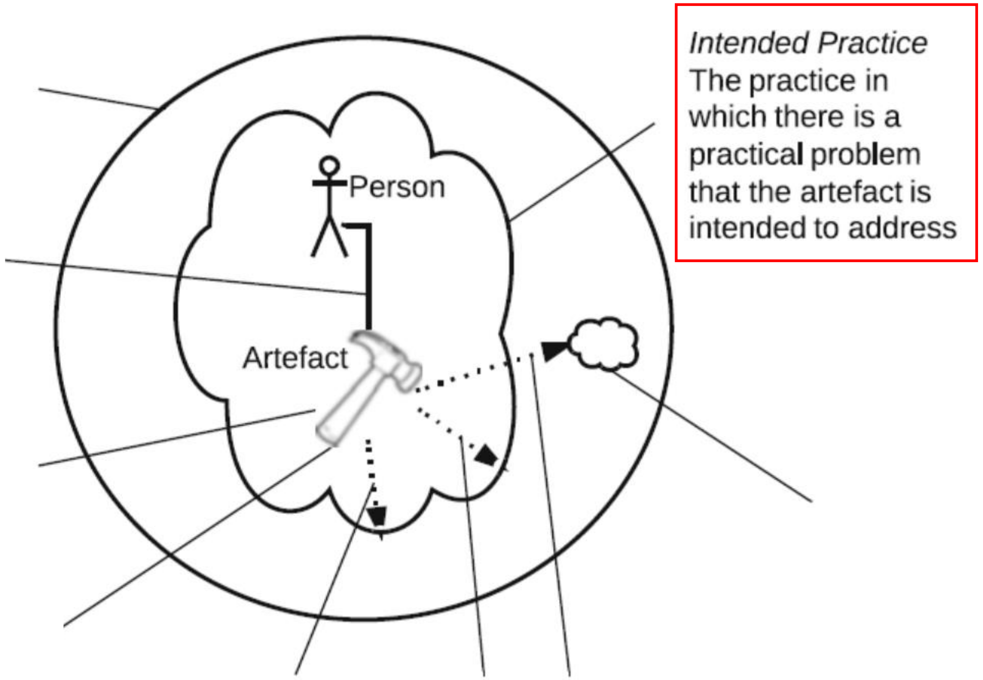
Artefact - Address – Problem

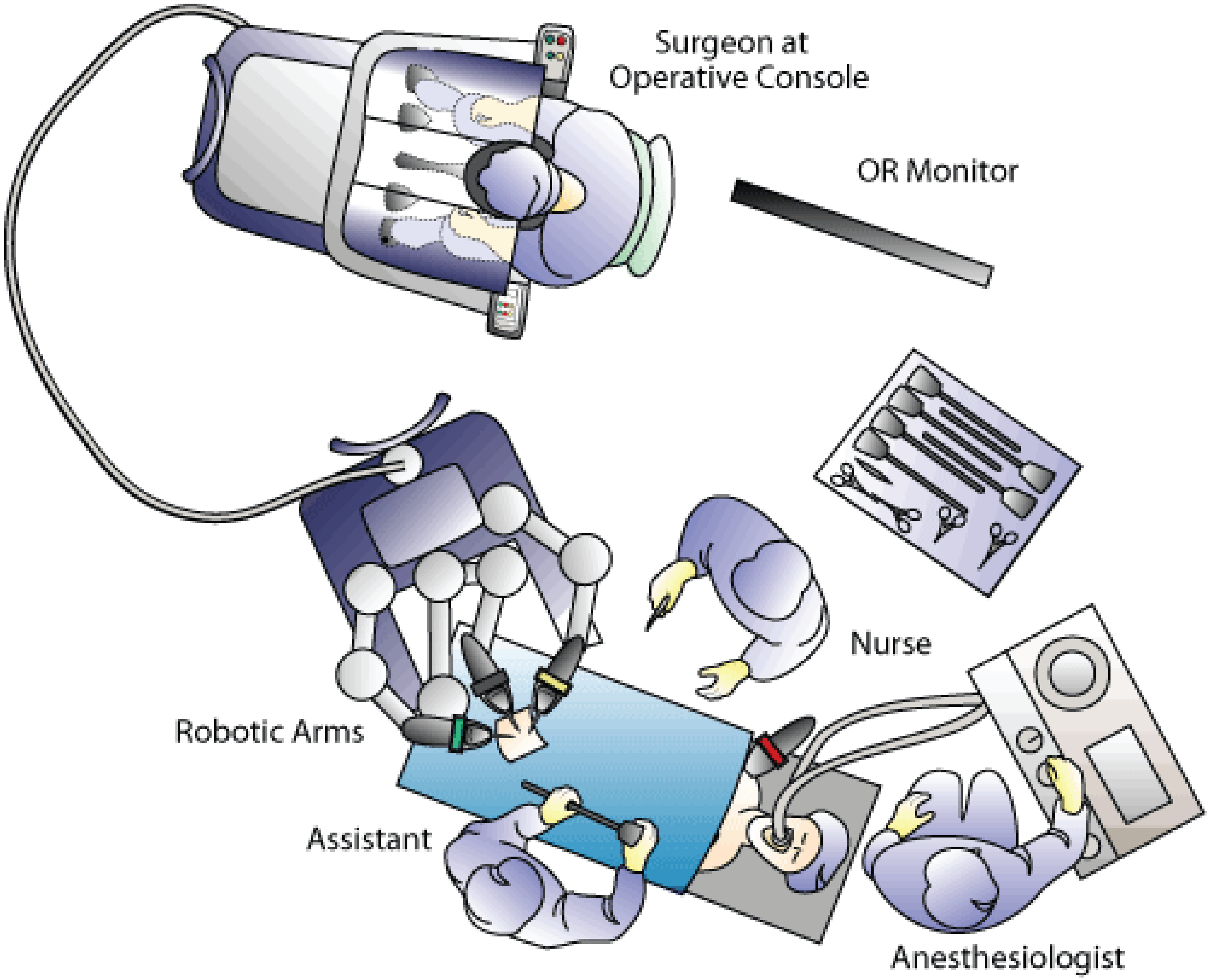
Q: How is the problem addressed

Artifact - Context and Anatomy

- **Intended Practice** – Intended practice is practice that contains the practical problem that the artefact addresses.



Intended Practice
The practice in which there is a practical problem that the artefact is intended to address

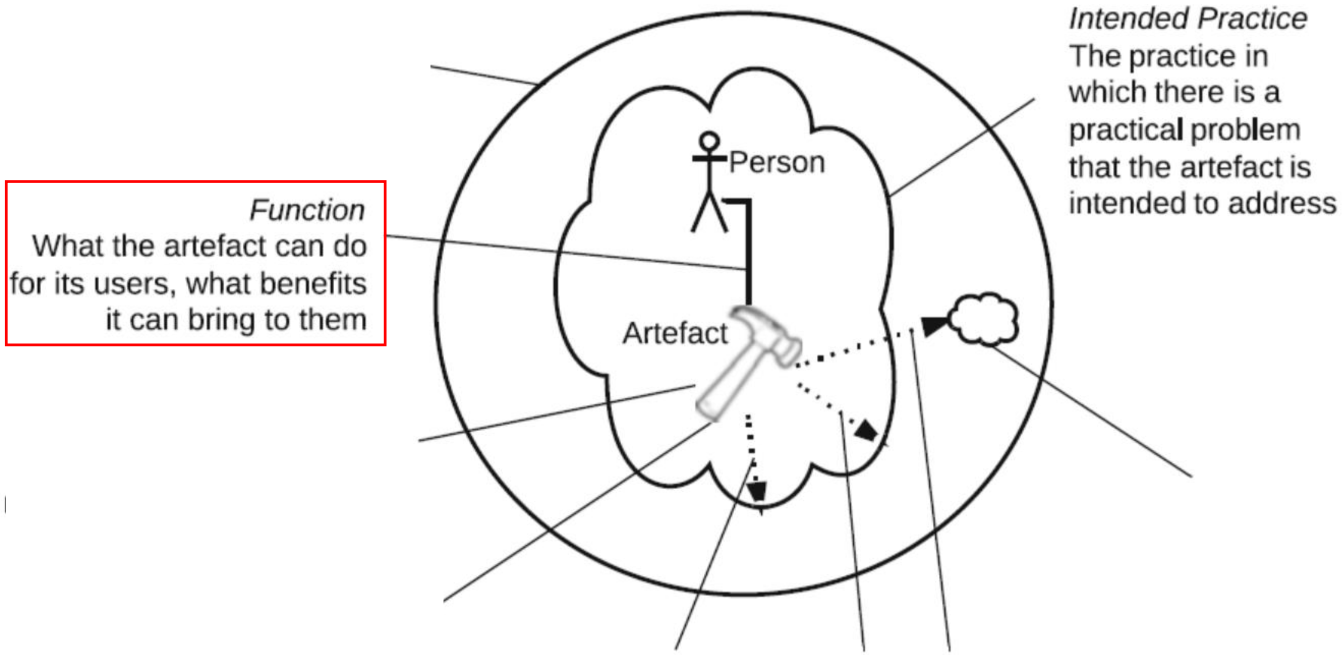


- **Intended Practice** – Intended practice is practice that contains the practical problem that the artefact addresses.

- **Robotics Surgery**

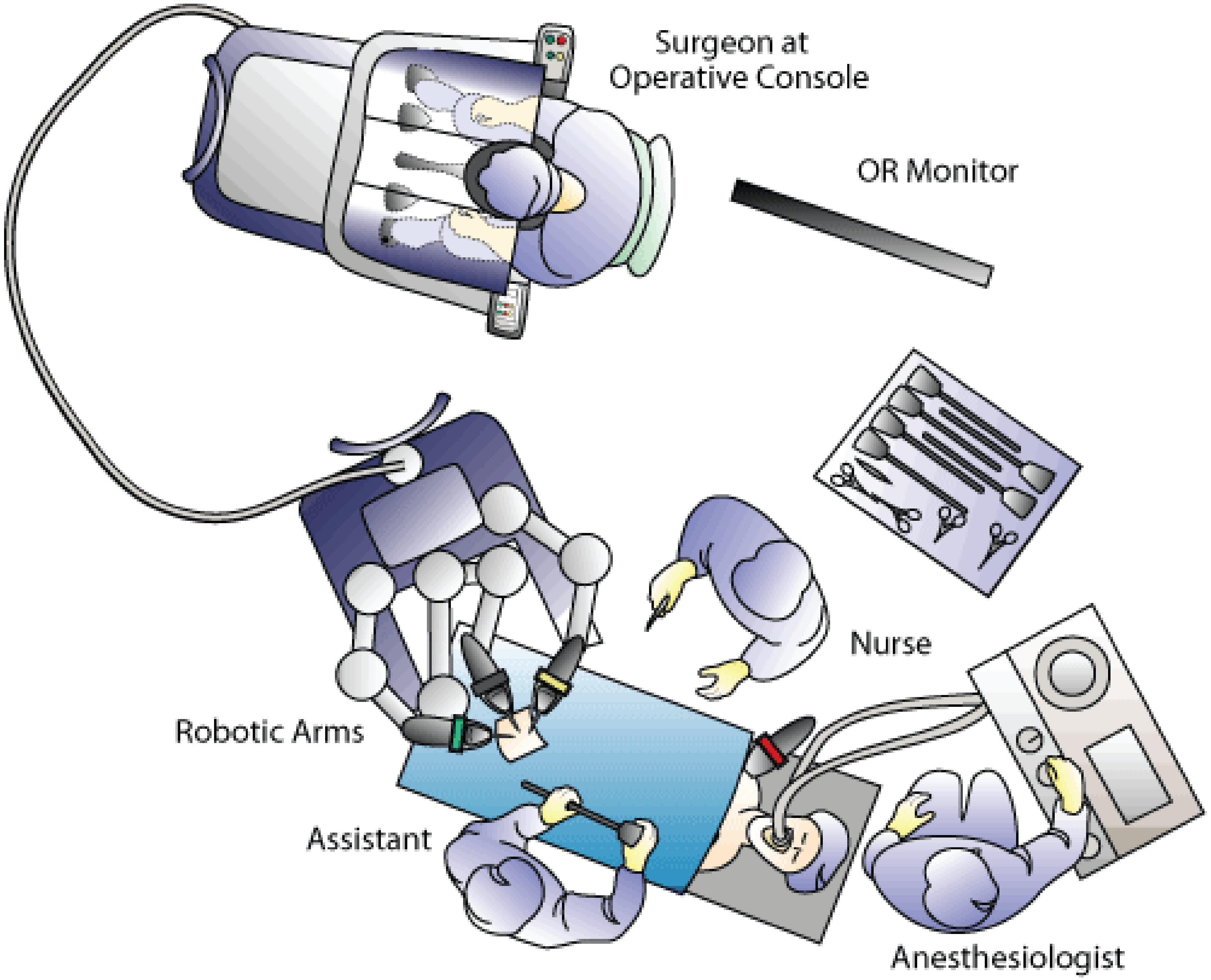
Artifact - Context and Anatomy

- **Functions**
  - **The artefact has been created to offer its functions.**
  - what it can **do** for its users,
  - what **benefits** it can bring to users in their practice
  - what **role** it can play for users
  - how it can **support** users in their activities.
- Examples
  - A function of a clock is to tell the time
  - A function of a lawn mower is to cut grass,
  - A function of a truck is to transport goods.



Function
What the artefact can do for its users, what benefits it can bring to them

Intended Practice
The practice in which there is a practical problem that the artefact is intended to address



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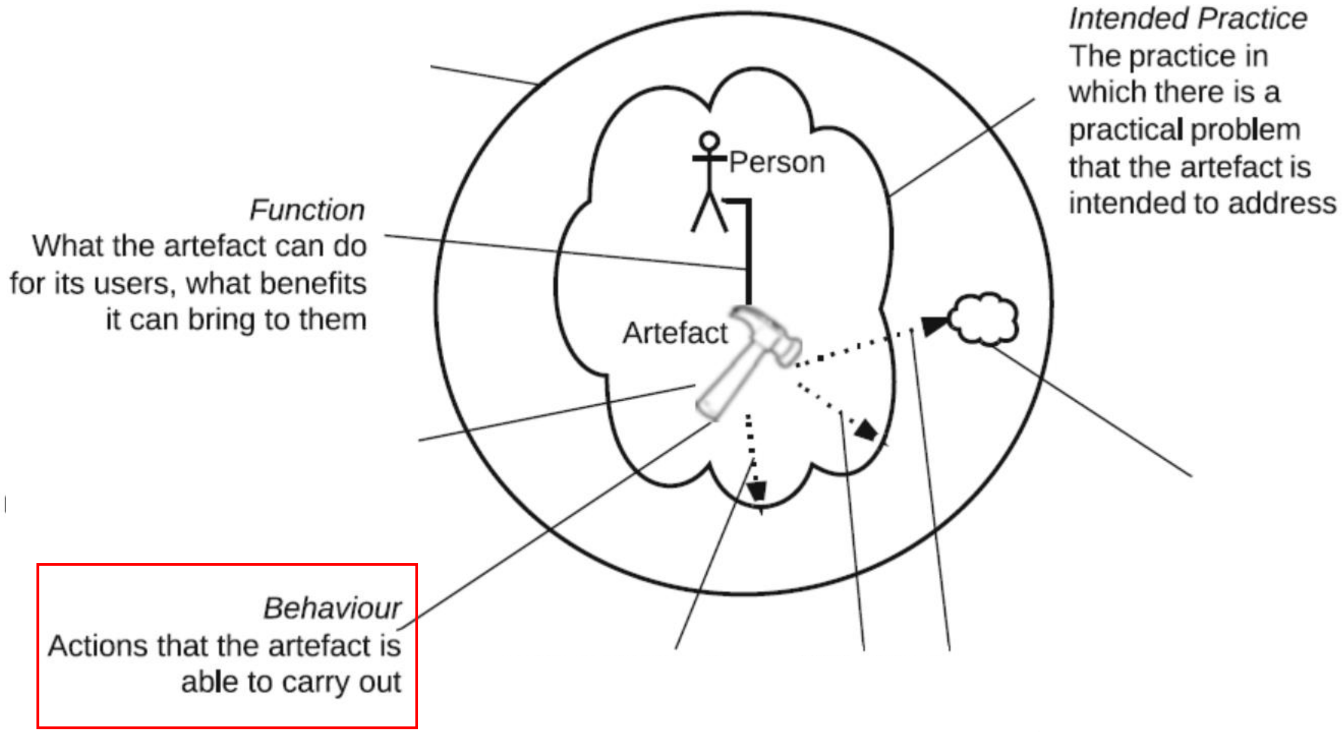
  - **The artefact has been created to offer its functions.**
  - what it can **do** for its users,
  - what **benefits** it can bring to users in their practice
  - what **role** it can play for users
  - how it can **support** users in their activities.

- **Do / Role**
  - Perform Robotics Surgery
- **Benefits**
  - High dexterity
  - Superior Vision
  - Quick Recovery
  - Minimal scars
  - Low risk of infection
- **Support**
  - Reduce the surgeon’s Cognitive load

Artifact - Context and Anatomy

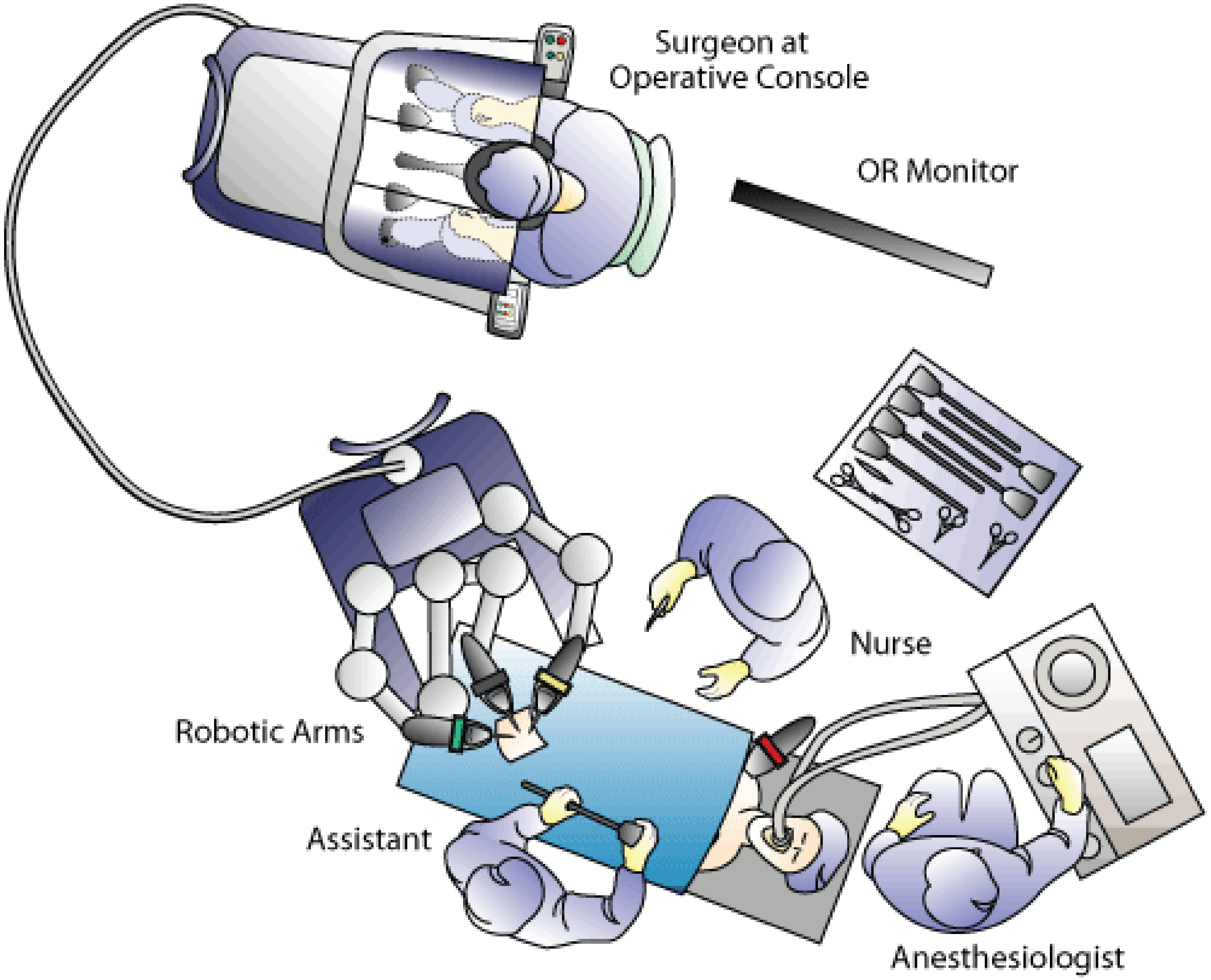
- **Behaviors (Relevant to its function)** - In order to be able to provide its functions, an artefact must be able to perform certain behaviors, i.e. it must be able to carry out various actions.
- Example- Behaviors of a truck are rolling, accelerating, braking, turning, and honking. These behaviors are all essential for the main function of the truck, to transport goods.
- **Behaviors (Irrelevant to its function)** – Behavior that that are not relevant to any of its functions,
- Example - The truck may make engine sounds and emit fumes, which are behaviors of the truck that are not needed for its transport function.
- Behavior Versus Function
  - Behavior is simply something that an artefact can do
  - Function is something that the artefact can do for the benefit of its users.
- Function is a relative concept that connects the behaviors of an artefact with the goals and activities of its users.



Intended Practice
The practice in which there is a practical problem that the artefact is intended to address

Function
What the artefact can do for its users, what benefits it can bring to them

Behaviour
Actions that the artefact is able to carry out



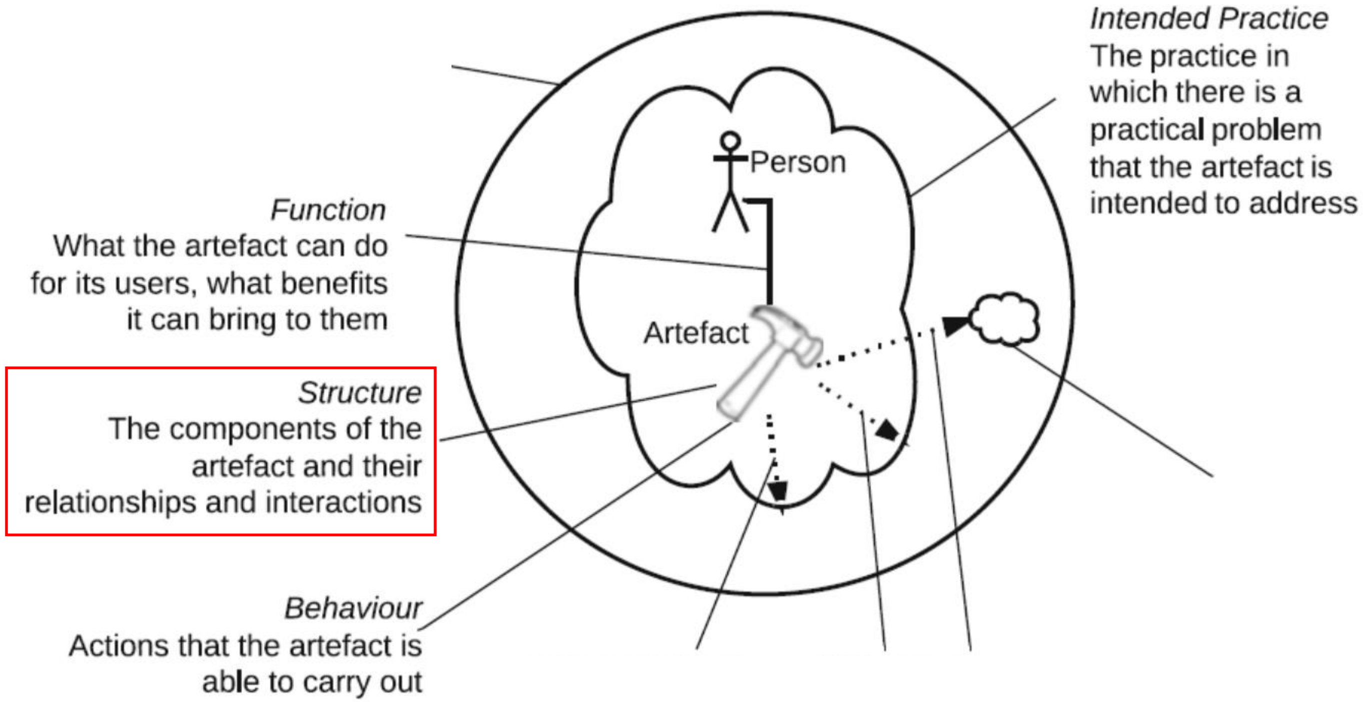
- **Behaviors (Relevant to its function)** –
- Manipulate surgical tools and endoscope

- **Behaviors (Irrelevant to its function)** –
- Surgical robotics tools may collide outside of the patient
- Pose a risk to the patient due to dysfunction
- Disrupt the communication and collaboration between the primary surgeon and the assistant

Artifact - Context and Anatomy

- **Structure (Inside of the Artifact)** - In order to produce its behaviors, the artefact has to be constructed and configured in a certain way. The structure of an artefact is about its inner workings, the components it consists of, how these are related, and how they interact with each other.

- Example: Clock constructed from cogwheels springs, body, interface
- Example: Truck made of a chassis, an engine, wheels,

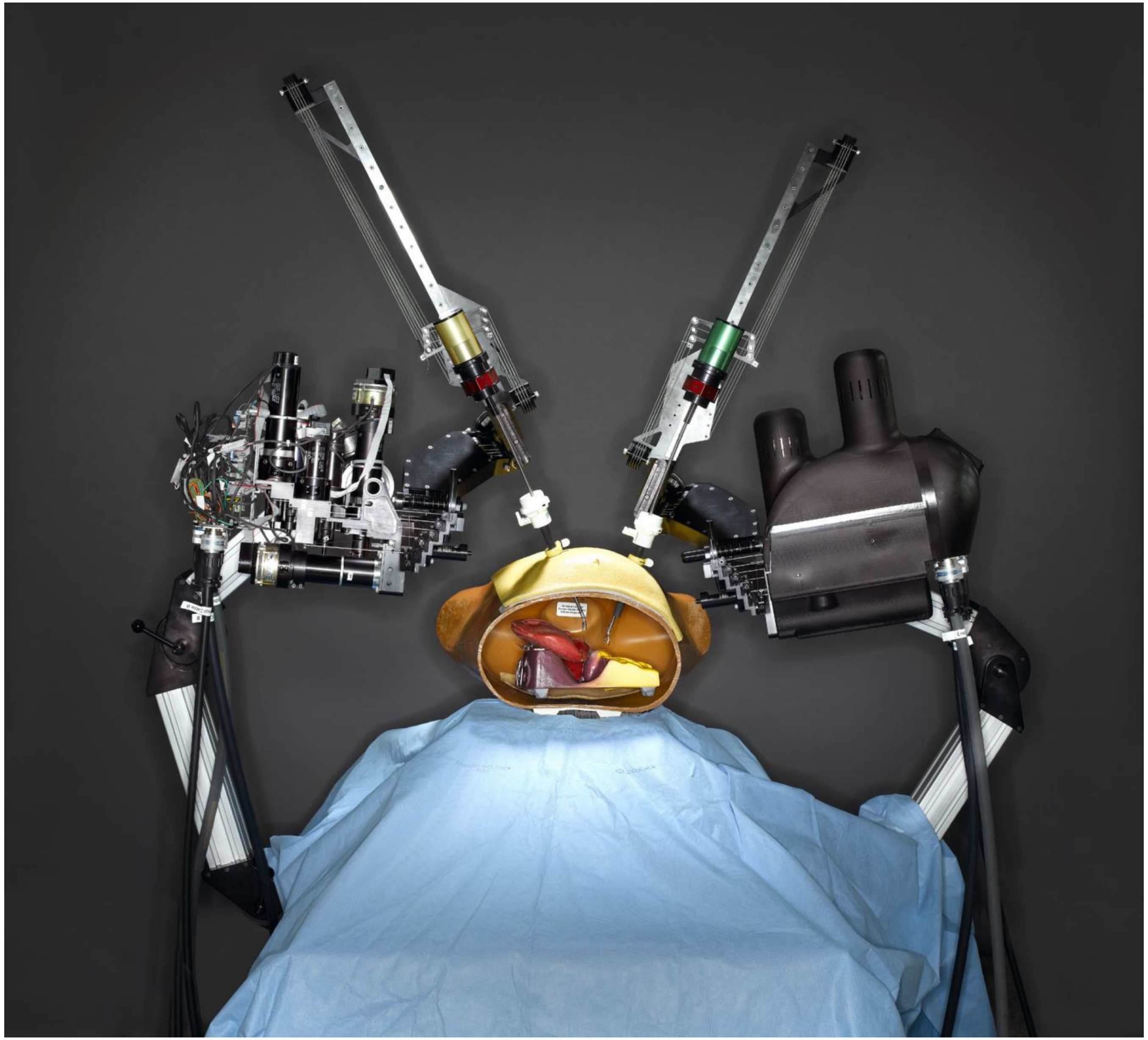


Intended Practice
The practice in which there is a practical problem that the artefact is intended to address

Function
What the artefact can do for its users, what benefits it can bring to them

Structure
The components of the artefact and their relationships and interactions

Behaviour
Actions that the artefact is able to carry out



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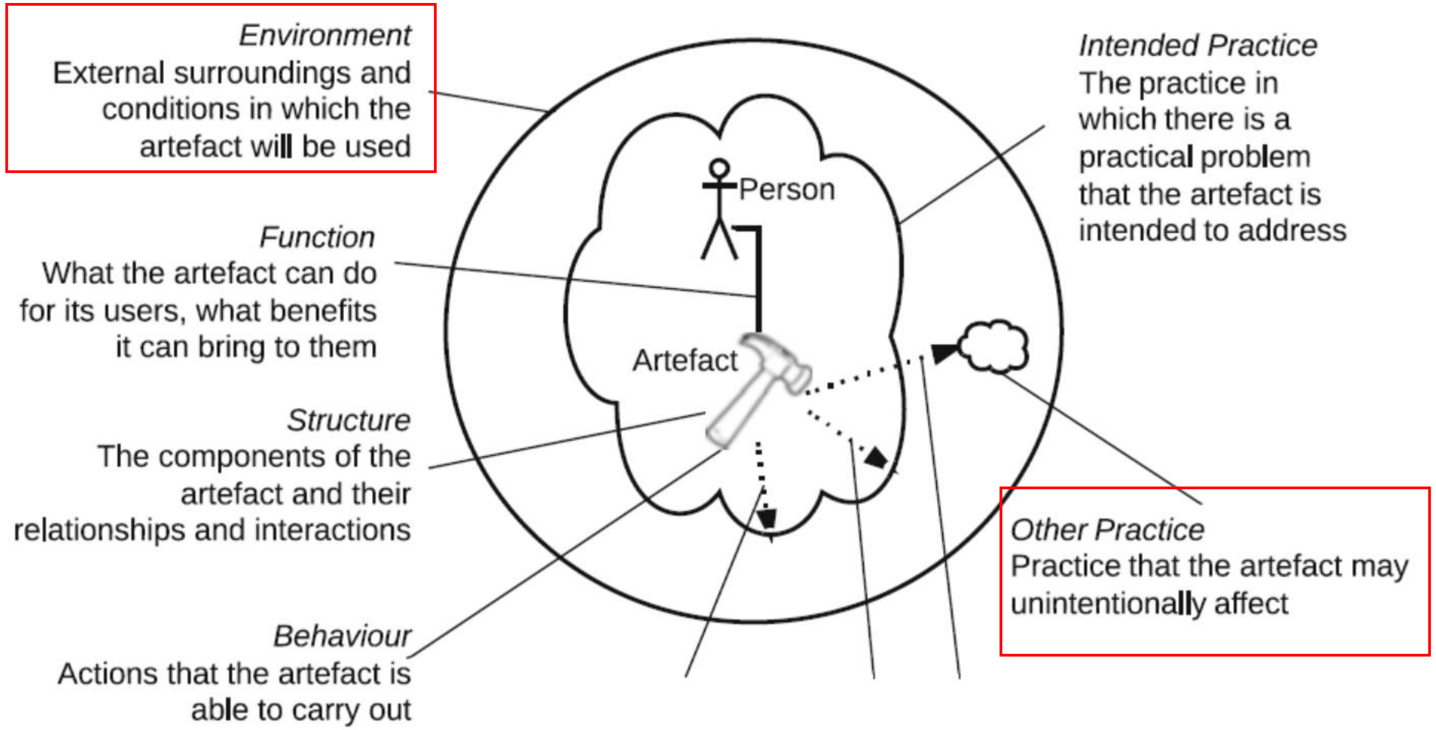
- **Surgical Robot**
  - **Long Surgical Robotics tools**
  - **Remote center of rotation**
  - **Cable driven mechanism**

Artifact - Context and Anatomy

- **Environment** - The environment of an artefact is about the outside, i.e. the external surroundings and conditions in which the artefact will operate.
- The environment of an artefact always encompasses its intended practice, including people and other objects participating in that practice.
- The environment may also include other practices that are affected by the use of the artefact, as well as various objects that are not related to any specific practice.
- Example
  - The environment of a truck includes the goods transportation practice, i.e. the intended practice.
  - If the truck passes through areas where kids are playing, the practice of children playing also becomes a part of the truck's environment.
  - Finally, the environment contains the physical surroundings of the truck, including streets and air.



Environment
External surroundings and conditions in which the artefact will be used

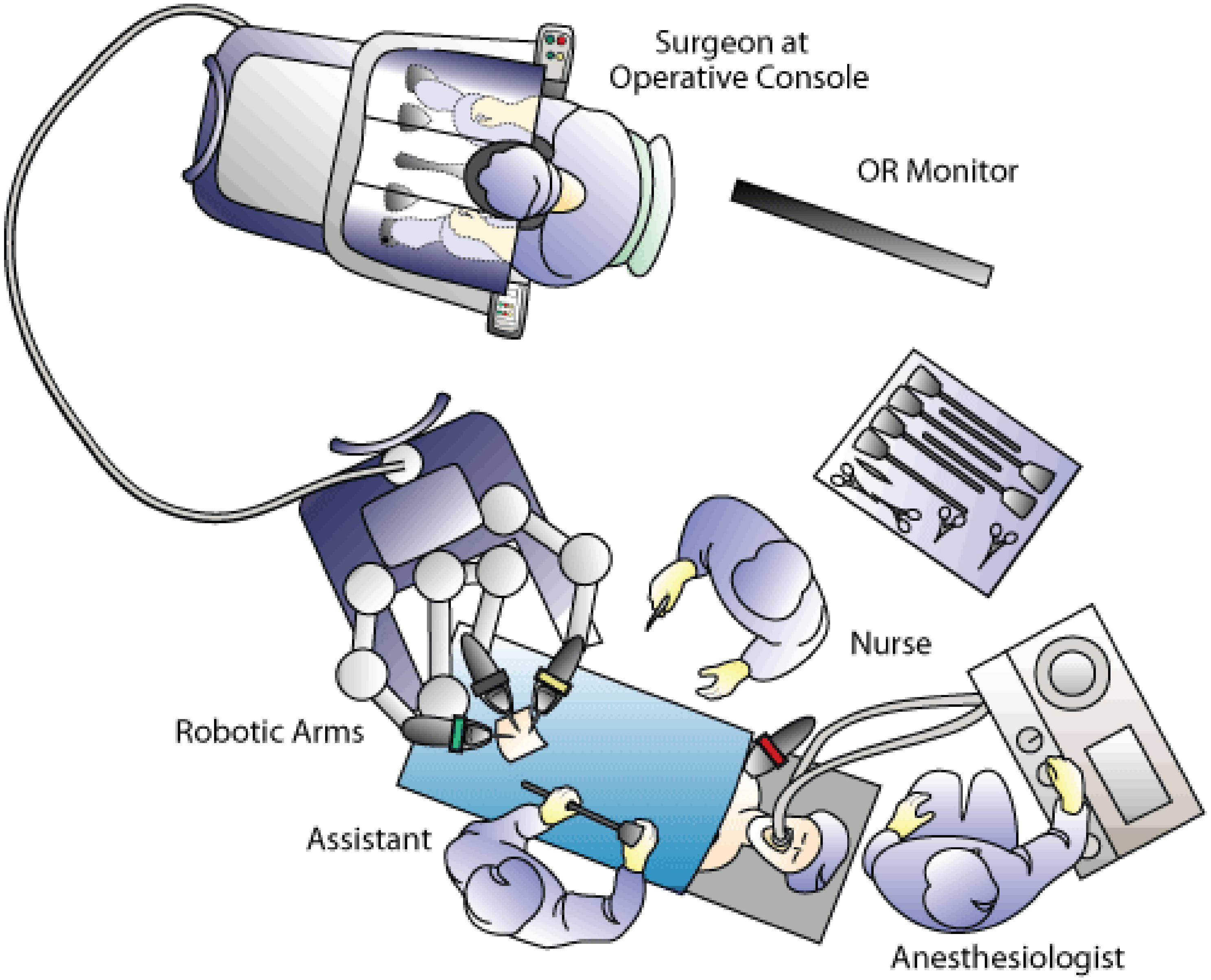
Function
What the artefact can do for its users, what benefits it can bring to them

Structure
The components of the artefact and their relationships and interactions

Behaviour
Actions that the artefact is able to carry out

Intended Practice
The practice in which there is a practical problem that the artefact is intended to address

Other Practice
Practice that the artefact may unintentionally affect



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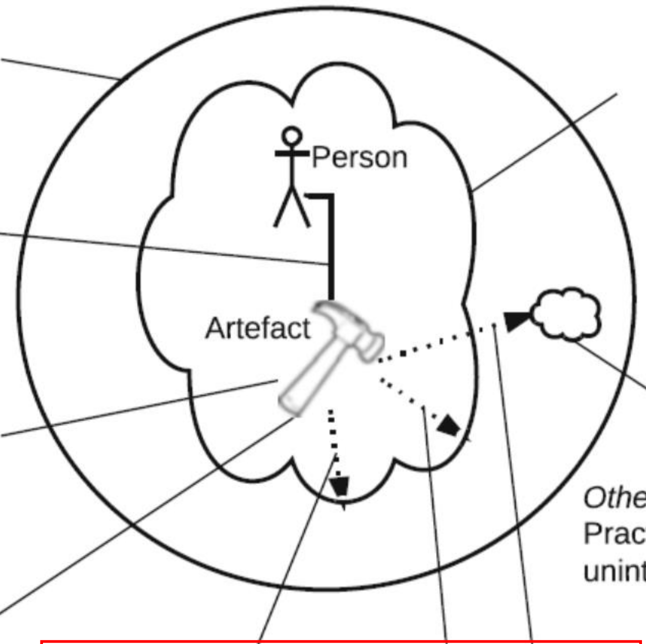
- **Environment**
  - Type 1 – Operating Room
  - Type 2 – Patient Body
- **People**
  - Surgeon
  - Assistant
  - Nurse
  - Anesthesiologist
- **Nature of the environment**
  - Sterile / Non Sterile
- **Other practices**
  - Anesthesiologist

Artifact - Context and Anatomy

- **Effects** - When an artefact is used in a practice, it will have certain effects on its environment, i.e. it will change it in intended as well as in unintended ways.
- **Intended Effects** – The intended effects are related to the functions of the artefact,
- Example - The intended effect of using a truck is that some goods are moved from one place to another.
- **The Unintended Effects (Side Effects)** - The unintended effects, often called side effects. These effects may concern not only the intended practice of the artefact but also other practices, sometimes with adverse consequences for them. Side effects may also be harmful for other valuable resources even if these are not used directly in any specific practice.
- Example - A truck passing through an area where children are playing may pose such a safety hazard that the play has to stop. Emissions from truck driving pollute the air, which may harm many practices indirectly.



Environment
External surroundings and conditions in which the artefact will be used

Function
What the artefact can do for its users, what benefits it can bring to them

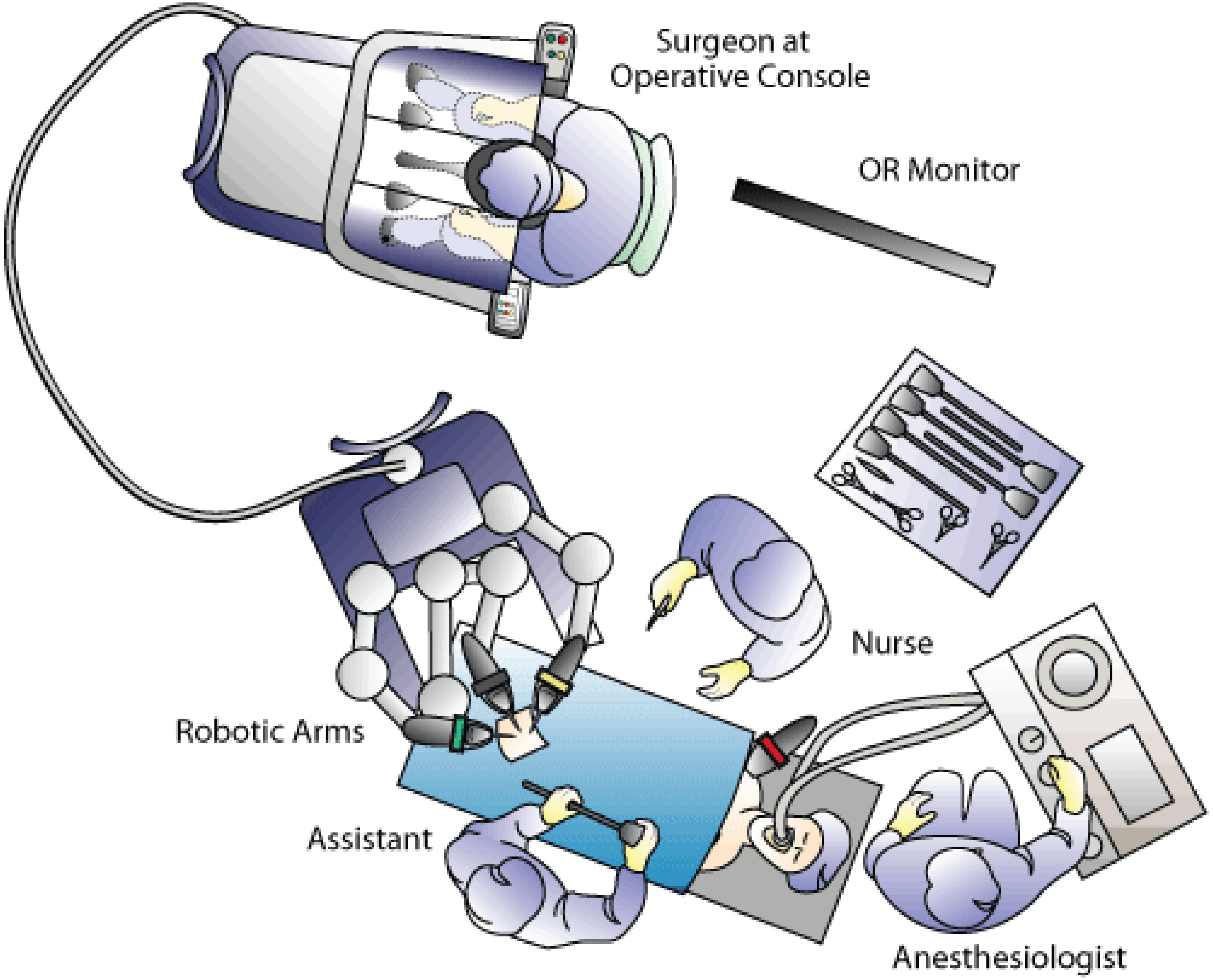
Structure
The components of the artefact and their relationships and interactions

Behaviour
Actions that the artefact is able to carry out

Intended Practice
The practice in which there is a practical problem that the artefact is intended to address

Other Practice
Practice that the artefact may unintentionally affect

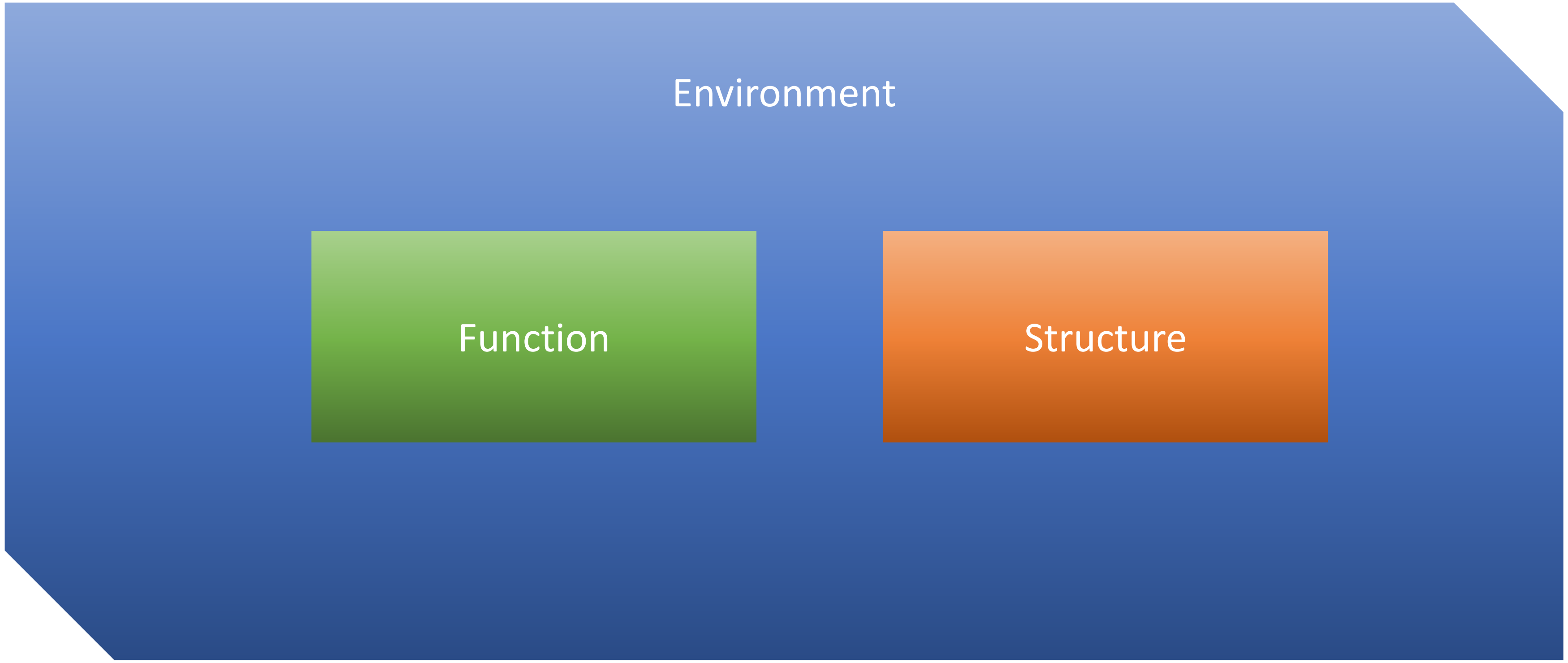
Intended Effects Intended effects caused by the use of the artefact	*Side Effects* Unintended effects caused by the use of the artefact



- **Effects** - When an artefact is used in a practice, it will have certain effects on its environment, i.e. it will change it in intended as well as in unintended ways.

- **Intendent Effects** – Change the anatomy / physiology of the patent body
- **Intendent Effects**
  - Bleeding
  - Tissue damage

Requirements – Structure & Function



Environment

Function

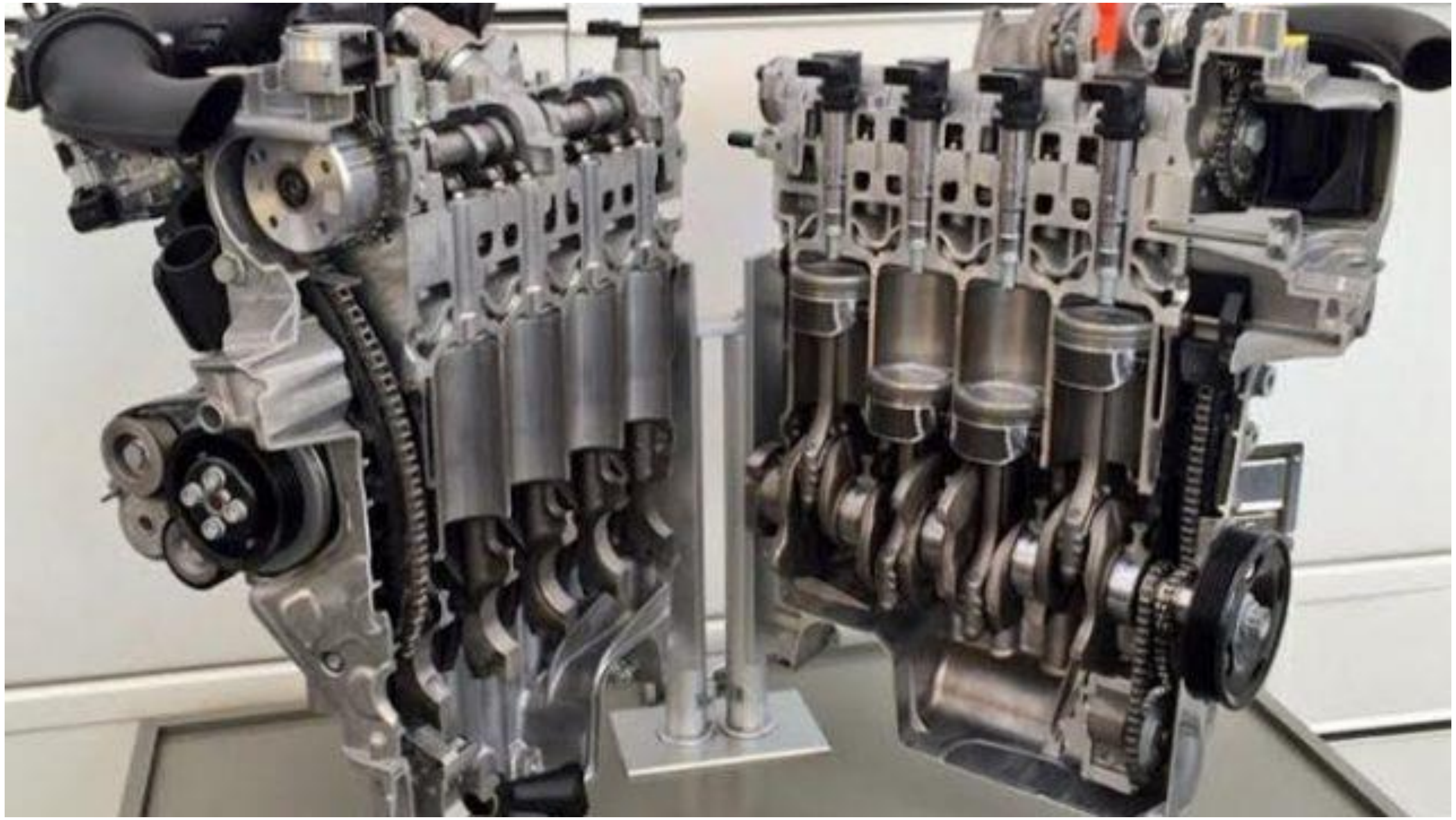
Structure

Requirements – Structure & Function Common Design Principle

- **Design Principles -** A common guiding principle in the design of an artefact is to
  - **Hide Structure** - Hide its structure from its future users. Users should not need to care about the internal structure of the artefact
  - **Explore Function** - Focus on its functions how it can serve them. Ideally, the users should not even be aware of the structure.

Requirements – Structure & Function Common Design Principle

Requirements – Structure & Function Common Design Principle



Requirements – Structure & Function Specific Occupation

- **Function & Structure in Specific Practice** - The distinction between structure, function, and environment is sometimes reflected in the professional roles of designers.
  - Example 1 - Construction Industry,
    - Engineer - a construction engineer will focus on the internal structure of buildings, including the selection of building materials, the layout of plumbing, the strength calculations, etc.
    - Architect – Architect will focus on the environment and functions of buildings in order to cater for external constraints as well as for the needs and requirements of the users.
  - Example 2 - IT and information systems industry,
    - Enterprise architects –
      - Business requirements
      - Legal issues,
      - Cultural factors
      - Environmental Aspects
    - Programmers and Software Engineers
      - construction of the software within the systems to be built.

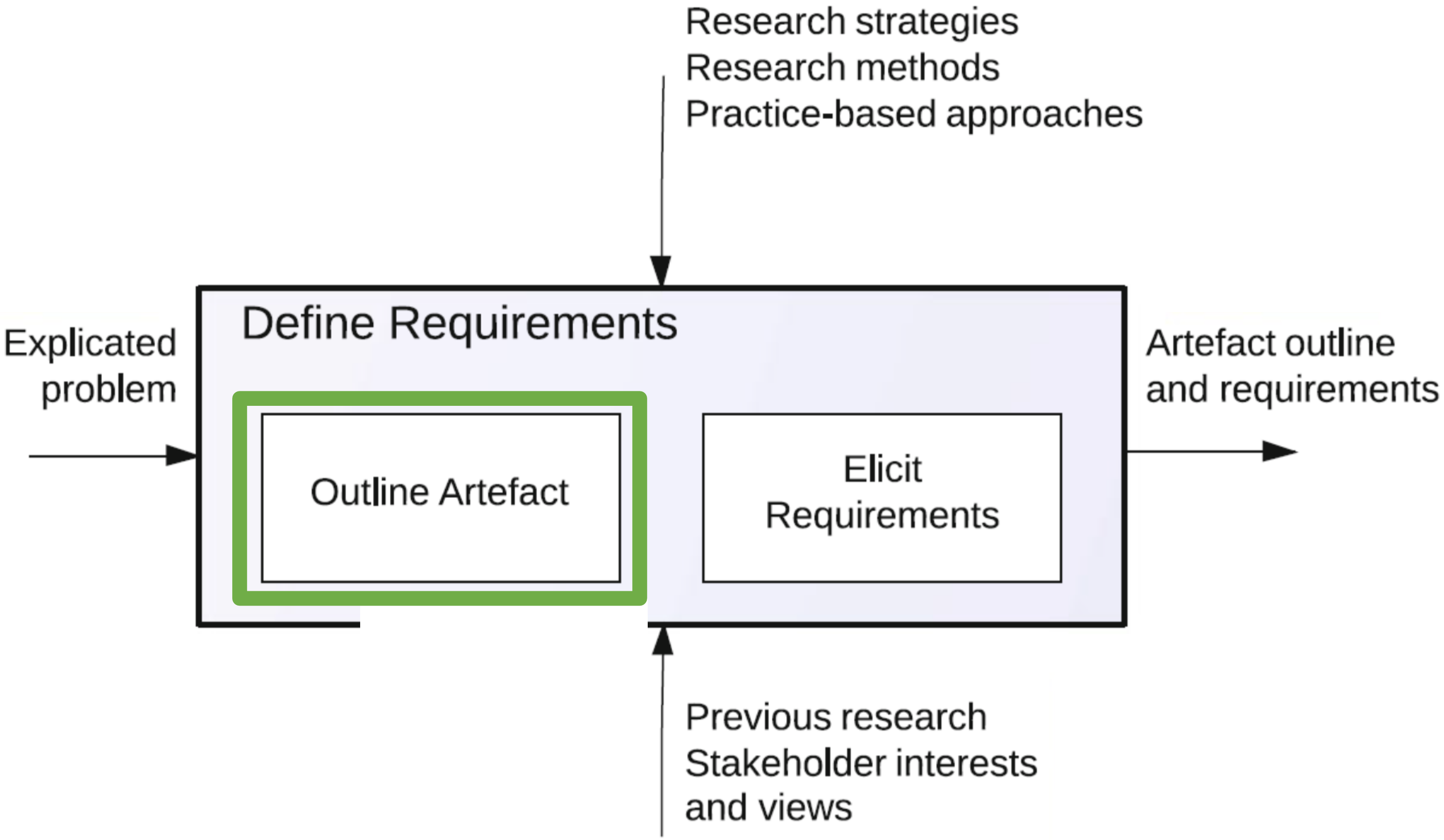
Types of Requirements – Functional Requirements

- **Functional Requirements** - When designing an artefact, a designer often starts by creating a specification that defines its functional requirements,
  - **Problem Related** - Depends on the problem to be addressed
  - **User Related Needs & Wants** - Functions that the artefact should offer to the users along with their needs and wants
  - **No reference to its structure** - The structure can be developed later on when the designer has a more complete understanding of the requirements
  - **Situation Related** - Very specific to the situation at hand.
    - Examples - Electronic health record system
      - Technical: Provide storage of imaging scanning (X-rays CT MRI)
      - User (Physician): Enable doctors to enter information about investigations and treatments,
      - Users (Patients): Allow patients to enter information on their self medication.

Types of Requirements –
Non Functional Requirements

- **None Functional Requirements** - Non-functional requirements on an artefact, i.e. requirements that do not address functionality but instead general qualities
  - Examples: security, usability, maintainability, and scalability.
- **Structural Requirements** – Structure of the artifact
  - Examples - Electronic health record system
    - Coherent and Modular design
- **Environmental Requirements** – Environment surrounding the artifact
  - Examples - Electronic health record system
    - Be available on different platforms
    - Be easy to adapt to changes
- **Usage Requirements - Goals on the effects of using an artefact**
  - Example - the use of a new IT system should
    - increase profits by 5% or
    - make the corporate culture less hierarchic.

Requirements – Definition



Research strategies
Research methods
Practice-based approaches

Explicated problem

Define Requirements

Outline Artefact

Elicit Requirements

Artefact outline and requirements

Previous research
Stakeholder interests and views

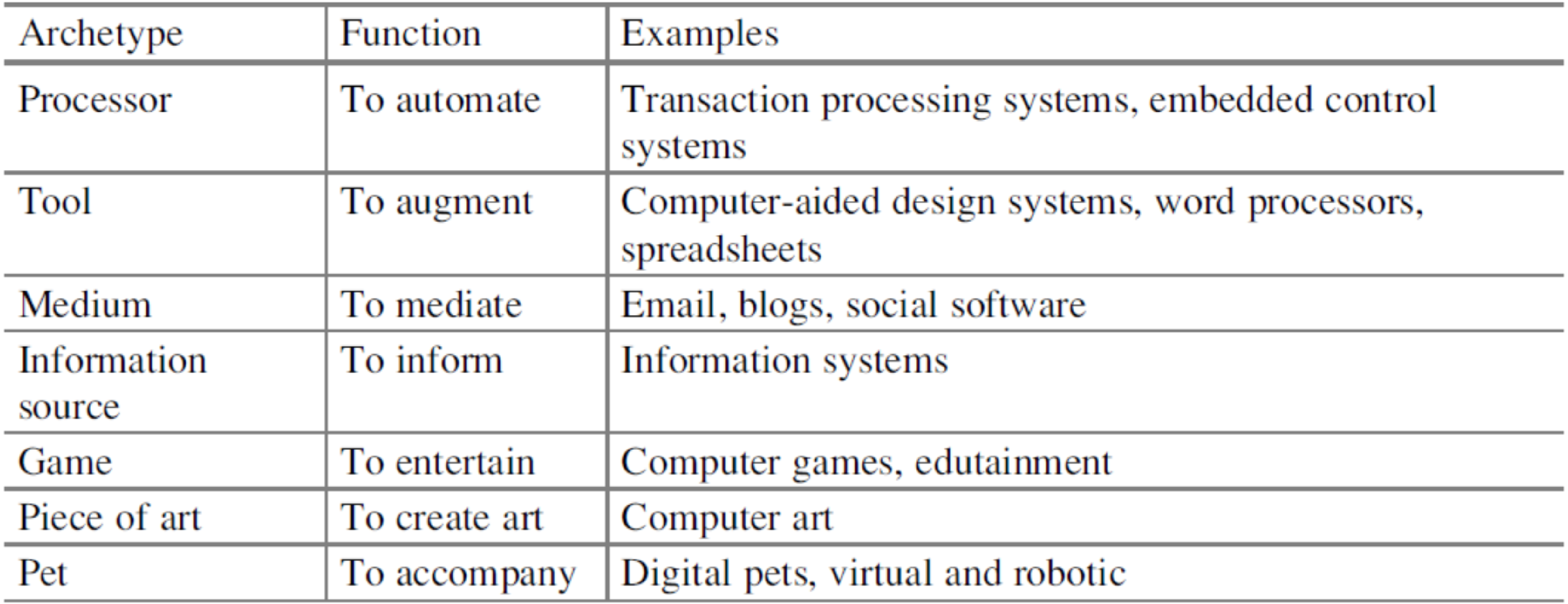
Artifacts Type 1
Constructs, Models, Methods, and Instantiations

- **Constructs** - Constructs are terms, notations, definitions, and concepts that are needed for formulating problems and their possible solutions. Constructs do not make any statements about the world, but they make it possible to speak about it, so it can be understood and changed. Thus, constructs are definitional knowledge. They are the smallest conceptual atoms with which to understand and communicate about various phenomena.
    - Form the vocabulary of a domain
    - Describe problems within the domain and specify their solutions
- **Models** - Models are representations of possible solutions to practical problems, so a model can be used for supporting the construction of other artefacts. For example, a drawing can be used for building a house, and a database model can be used for developing a database system. As models prescribe the structure of other artefacts, they express prescriptive knowledge. A model is built up from constructs that ar
    - Combination of constructs
    - Represent situations as problem and solution statements
    - Concern of models is utility e related to each other.

Artifacts Type 1
Constructs, Models, Methods, and Instantiations

- **Methods** - Methods express prescriptive knowledge by defining guidelines and processes for how to solve problems and achieve goals. In particular, they can prescribe how to create artefacts. Methods can be highly formalized like algorithms, but they can also be informal such as rules of thumb or best practices. Some examples are methods for database design, change management initiatives, or web service development.
    - Set of steps used to perform a task and/or solve a problem
    - Based on a set of underlying constructs and models of the solution space
    - Methodological tools are used by natural scientists
    - e.g. an algorithm or manual
- **Instantiations** - Instantiations are working systems that can be used in a practice. Instantiations can always embed knowledge, e.g. a database can embed a database model. Some examples of instantiations are a Java program realising a search algorithm, a database for electronic medical records, or a new planet in the computer game Entropia.
    - Realization of artifacts in its environment
    - Demonstrate the feasibility and effectiveness of the models and methods they contain
    - Their study can lead to significant advancements in design and natural science
    - e.g. software, hardware

Artifacts Type 2
A Function-Oriented Artefact Classification

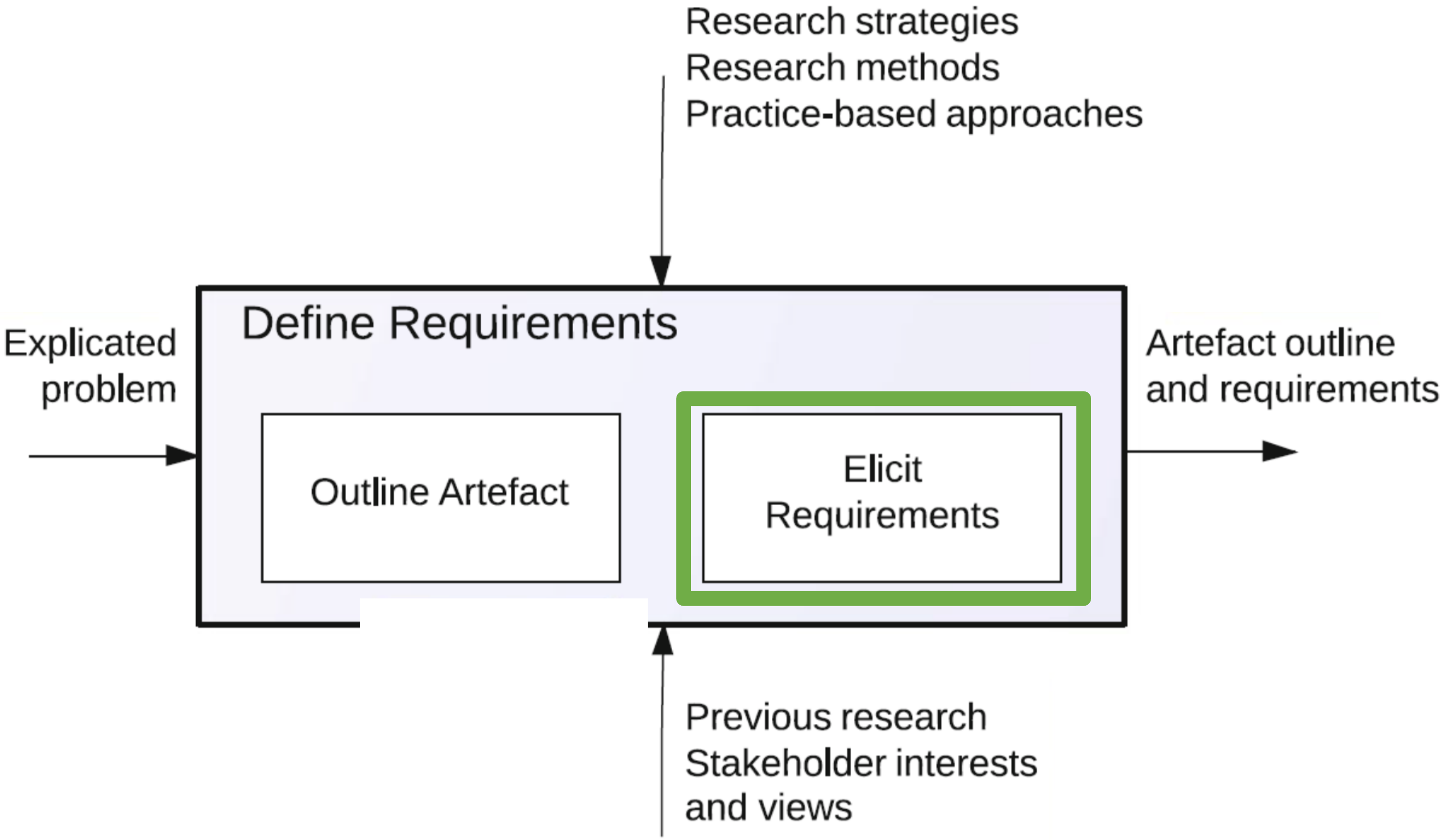


Archetype	Function	Examples
Processor	To automate	Transaction processing systems, embedded control systems
Tool	To augment	Computer-aided design systems, word processors, spreadsheets
Medium	To mediate	Email, blogs, social software
Information source	To inform	Information systems
Game	To entertain	Computer games, edutainment
Piece of art	To create art	Computer art
Pet	To accompany	Digital pets, virtual and robotic

Artifacts Type 3
A Pragmatic Artefact Classification

- **System Design** - A structure or behavior-related description of a system, typically using text and some formal language
- **Method** - A definition of activities to create or interact with a system
- **Language/Notation** - A (formalized) system to formulate statements about some domain
- **Algorithm** - An executable description of system behavior
- **Guideline** - A suggestion regarding behavior in a particular situation
- **Requirements** - A statement about required behavior and functions of a system
- **Pattern** - A definition of reusable design elements with their benefits and application context
- **Metric** - A mathematical model able to measure aspects of systems or methods

Requirements – Definition



Research strategies
Research methods
Practice-based approaches

Explicated problem

Define Requirements

Outline Artefact

Elicit Requirements

Artefact outline and requirements

Previous research
Stakeholder interests and views

Elicit Requirements – Activities & Methods

Activities	Methods
Clarifying Objectivities	Objective Tree Method
Establishing Functions	Function Analysis Method
Setting Requirements	Performance Specification Method
Determining Characteristics	Quality Function Deployment Methods

Objective Tree Method

Clarifying Objectives

Clarifying Objectivities – Introduction

- **Aim** - The aim of the objectives tree method is to clarify design objectives and sub objectives, and the relationships between them.
- **Initial Approach – A simply a 'problem' that needs a solution – Vague Need** - When a client, sponsor or company manager first approaches a designer with a product need, the client perhaps knows only the type of product that is wanted, and has little idea of the details, or of the variants that might be possible. Or the 'need‘ might be much vaguer still: simply a 'problem' that needs a solution.
- **Starting Point – Ill Defined Problem with Vague Requirements** - The starting point for design work is therefore very often an ill defined problem, or a rather vague requirement.
- **End Point - Objective Statement for Defining the End Goal** - It will be quite rare for a designer to be given a complete and clear statement of design objectives. Yet the designer must have some objectives to work towards. The outcome of designing is a proposal for some means to achieve a desired end. That 'end' is the set of objectives that the designed object should meet.
- **Clarify the Design Objectives May Change Over Time** - An important first step in designing therefore is to try to clarify the design objectives. In fact, it is very helpful at all stages of designing to have a clear idea of the objectives, even though those objectives may change as the design work progresses. The initial and interim objectives may change, expand or contract, or be completely altered as the problem becomes better understood and as solution ideas develop. So it is quite likely that both' ends' and 'means' will change during the design process.

Clarifying Objectivities – Introduction

- **Clear and Agreed (Stakeholder/ Designer) Statement of Objectives** - As an aid to controlling and managing the design process it is important to have, at all times, a statement of objectives which is as clear as possible. This statement should be in a form which is easily understood and which can be agreed by the client and the designer, or by the various members of the design team. (It is surprising how often members of the same team can have different objectives!)
- **Objectives Tree Method** -
  - **Clear & Simple Format** - Offers a clear and useful format for a statement of objectives
  - **Objectives & Means** - Shows the objectives and the general means for achieving them
  - **Relationships Between Objectives (Hierarchy)** - Ways in which different objectives are related to each other and the hierarchical pattern of objectives and sub objectives.
  - **Agreement** - Reach agreement between clients, managers and members of the design team

Objective Tree Method – Procedure
Step 1 - Prepare a list of design objectives

- **Prepare a List of Design Objective** - Mixture of abstract and concrete aims that the design must try to satisfy or achieve.
    - Client requirements
    - User needs
    - Product purpose.
    - Example,
        - Set No. 1 - Safety,
        - Set No. 2 – Effectiveness
        - Set No. 3 – Reliability
        - Set No. 4 – Cost
        - Set No. 5 – Performance
        - Set No. 6 – Comfort
        - Set No. 7 – Eco – Friendly
        - Example: 'The product must be safe and reliable'.
- **Ask ‘What is Meant by that Statement** - Try to specify what it means. Ask 'what is meant by that statement?‘
        - Example: an objective for a machine tool that it must be 'safe', might be expanded to mean:
            1. Low risk of injury to operator.
            2. Low risk of operator mistakes.
            3. Low risk of damage to work piece or tool.
            4. Automatic cut-out on overload.
- Clarify the Objective by **Asking WH questions - 'why?', 'how?'** and 'what?'
        - Example
            - **‘Why do we want to achieve this objective?'**
            - **‘How can we achieve it?'**
            - ‘What implicit objectives underlie the stated ones?'
            - ‘What is the problem really about?'

Objective Tree Method – Procedure
Step 2 - Order the list into sets of higher-level and lower-level objectives

- **Order the each set of objective from high level to Low level objective.**
  - Example – For the Safety Set
    1. Machine must be safe
    2. Low risk of injury to operator
    3. Low risk of operator mistakes
    4. Low risk of damage to work piece or tool
    5. Automatic cut-out on overload

Objective Tree Method – Procedure
Step 2 – Generic List of Qualities / Objectives

- **Structural Qualities** – concern the structure of an artefact:
  - **Coherence**—the degree to which the parts of an artefact are logically, orderly, and consistently related; coherence is low if an artefact includes parts that, in some sense, do not fit in with the rest of the artefact.
  - **Consistence** (only for models)—the degree to which a model is free from conflicts.
  - **Modularity**—the degree to which an artefact is divided into components that may be separated and recombined; common requirements related to modularity are low coupling, i.e. modules are not overly related with each other; high cohesion, i.e. modules are highly related internally; and high composability, i.e. modules can be easily replaced and recombined.
  - **Conciseness**—the absence of redundant components in an artefact, i.e. components the functions of which can be derived from other components.

Objective Tree Method – Procedure
Step 2 – Generic List of Qualities / Objectives

- **Usage qualities** describe how an artefact should work and be perceived in use situations:
  - **Usability**—the ease with which a user can use an artefact to achieve a particular goal
  - **Comprehensibility**—the ease with which an artefact can be understood or comprehended by a user (also called understandability)
  - **Learnability**—the ease with which a user can learn to use an artefact
  - **Customisability**—the degree to which an artefact can be adapted to the specific needs of a local practice or user
  - **Suitability**—the degree to which an artefact is tailored to a specific practice, focusing only on its essential aspects (also called inherence or precision)
  - **Accessibility**—the degree to which an artefact is accessible by as many users as possible
  - **Elegance**—the degree to which an artefact is pleasing and graceful in appearance or style (also called aesthetics)
  - **Fun**—the degree to which an artefact is attractive and fun to use
  - **Traceability** (only for methods)—the ability to verify the history of using a method by means of documentation

Objective Tree Method – Procedure
Step 2 – Generic List of Qualities / Objectives

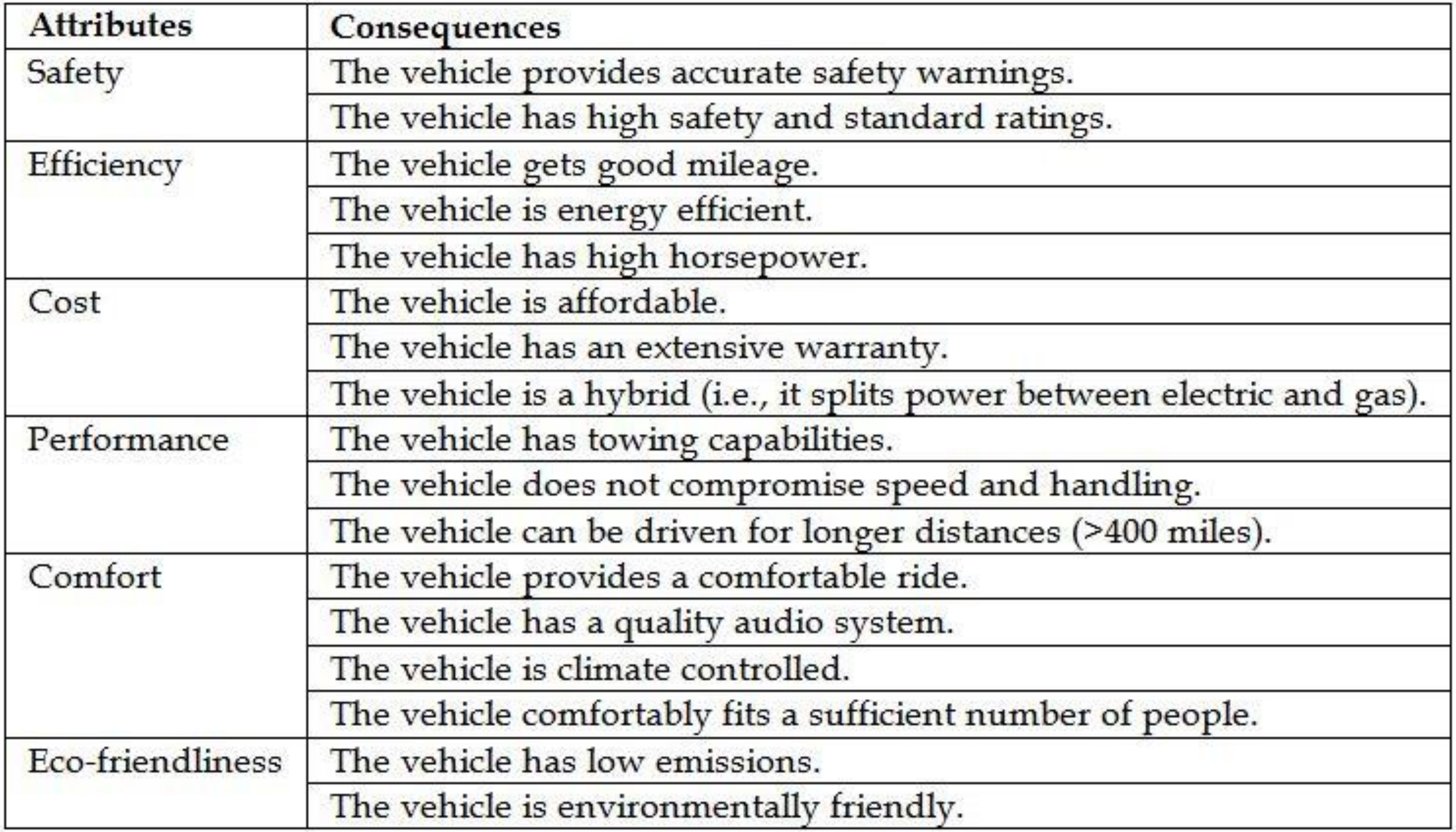
- **Management qualities** describe how an artefact should be managed over time:
- **Maintainability**—the ease with which an artefact can be maintained in order to correct defects, meet new requirements, make future maintenance easier, or cope with a changed environment.
- **Flexibility**—the ease with which an artefact can be adapted when external changes occur (similar to maintainability; related notions are configurability, evolvability, and extensibility).
- **Accountability**—the ease with which an actor can be made accountable for the workings of an artefact (a similar notion is auditability).

Objective Tree Method – Procedure
Step 2 – Generic List of Qualities / Objectives

- **Generic environmental qualities** mainly describe how an artefact should be structurally related to its environment:
  - **Expressiveness** (only for constructs and models)—the degree to which a set of constructs or a model is capable of representing the entities of interest in a Domain
  - **Correctness** (only for models)—the degree to which a model corresponds to the domain it represents (also called accurateness)
  - **Generality**—the degree to which an artefact is relevant not only for a local but also for a global practice Interoperability (only for instantiations)—the ability of an artefact to work together with other artefacts, in particular, to exchange data (related notions are openness, compatibility, and compliance with standards)
  - **Autonomy** (only for instantiations)—the capacity of an artefact to function without the involvement of another system
  - **Proximity** (only for models)—the degree to which independent aspects of a domain are captured by different constructs, and related aspects are represented by related constructs
  - **Completeness**—the degree to which an artefact includes all components required for addressing the problem for which it has been created
  - **Effectiveness**—the degree to which an artefact is able to achieve its goals
  - **Efficiency**—the degree to which an artefact is effective without wasting time, effort, or expense
  - **Robustness** (only for instantiations)—the ability of an artefact to withstand environmental change without adapting its construction
  - **Resilience** (only for instantiations)—the ability of an artefact to adapt itself when faced with major environmental change (related notions are degradability, survivability, and safety)

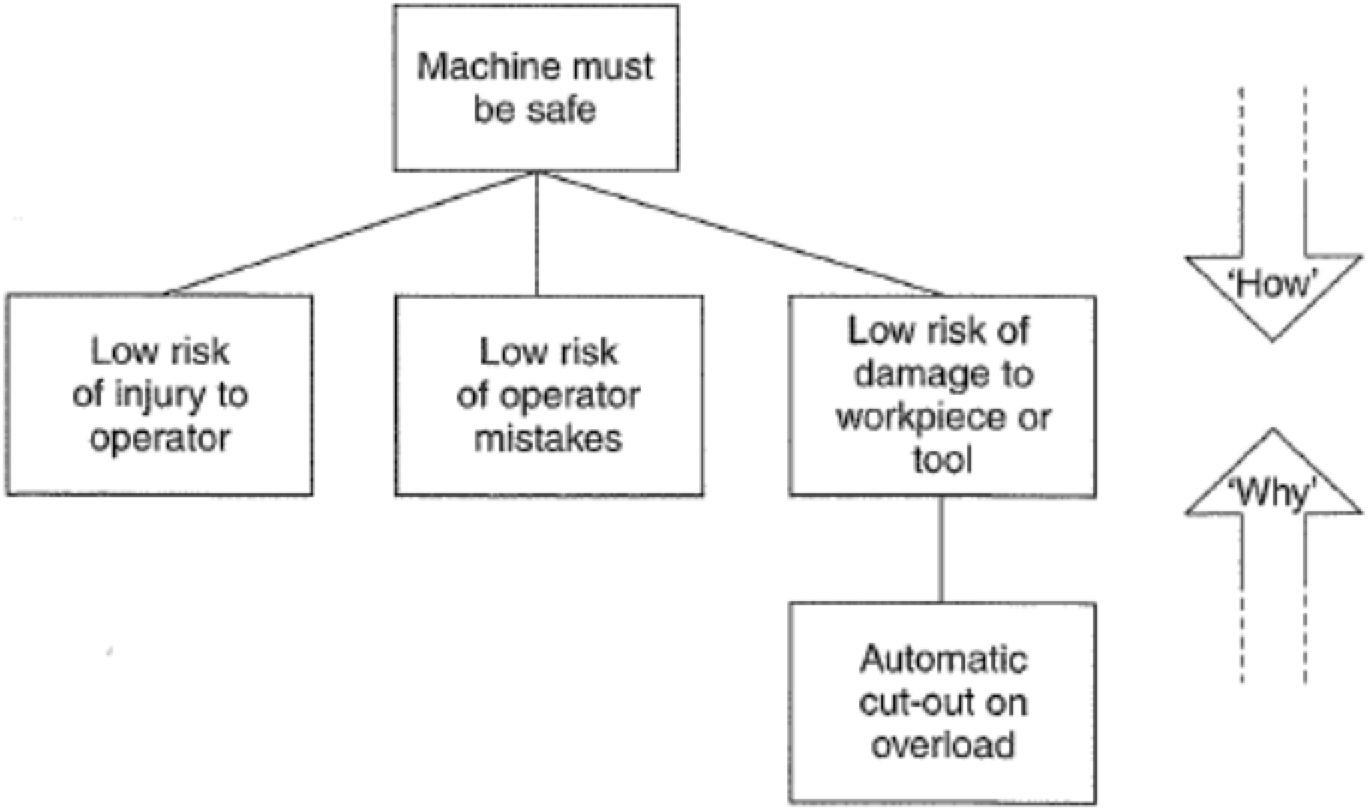
Objective Tree Method – Procedure
Step 2 – Generic List of Qualities / Objectives

- **5Es framework** that includes only five high-level qualities: efficacy, efficiency, effectiveness, elegance, and ethicality:
  - **Efficacy**—the degree to which an artefact produces desirable effects under ideal circumstances. For example, a weight-loss diet has high efficacy if people strictly following it actually lose weight.
  - **Efficiency**—the degree to which an artefact is effective without wasting time, effort, or expense. For example, a weight-loss diet is efficient if it is not expensive and does not require too much time to follow it.
  - **Effectiveness**—the degree to which an artefact produces desirable effects in practice. For example, a weight-loss diet has low effectiveness if people, due to various situational factors, are not able to follow it in their daily life. However, the diet can still have high efficacy; thus, efficacy and effectiveness are not the same.
  - **Elegance**—the degree to which an artefact is pleasing and graceful in appearance or style. For example, a weight-loss diet is elegant if it tastes good and is visually pleasing.
  - **Ethicality**—the degree to which the use of an artefact adheres to ethical norms. For example, a weight-loss diet including meat consumption may not be viewed as ethical according to some norms.



Attributes	Consequences
Safety	The vehicle provides accurate safety warnings.
	The vehicle has high safety and standard ratings.
Efficiency	The vehicle gets good mileage.
	The vehicle is energy efficient.
	The vehicle has high horsepower.
Cost	The vehicle is affordable.
	The vehicle has an extensive warranty.
	The vehicle is a hybrid (i.e., it splits power between electric and gas).
Performance	The vehicle has towing capabilities.
	The vehicle does not compromise speed and handling.
	The vehicle can be driven for longer distances (>400 miles).
Comfort	The vehicle provides a comfortable ride.
	The vehicle has a quality audio system.
	The vehicle is climate controlled.
	The vehicle comfortably fits a sufficient number of people.
Eco-friendliness	The vehicle has low emissions.
	The vehicle is environmentally friendly.

Objective Tree Method – Procedure
Step 3 - Draw a diagrammatic tree of objectives



Machine must be safe

Low risk of injury to operator

Low risk of operator mistakes

Low risk of damage to workpiece or tool

Automatic cut-out on overload

Objective Tree Method – Summary

- **Aim** - The aim of the objectives tree method is to clarify design objectives and sub objectives, and the relationships between them.

1. Prepare a list of design objectives. These are taken from the design brief, from questions to the client and from discussion in the design team.

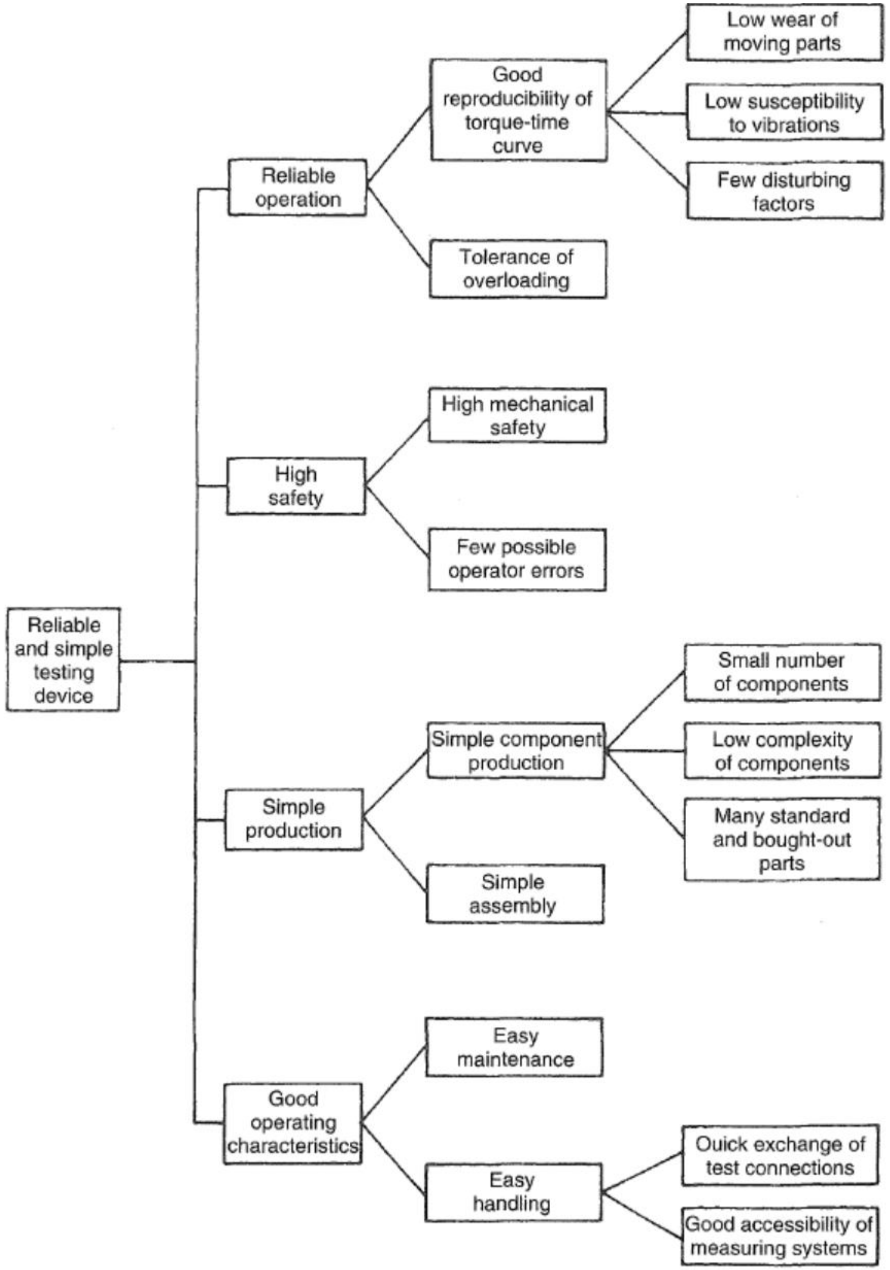
2. Order the list into sets of higher-level and lower-level objectives. The expanded list of objectives and sub objectives is grouped roughly into hierarchical levels.

3. Draw a diagrammatic tree of objectives, showing hierarchical relationships and interconnections. The branches (or roots) in the tree represent relationships which suggest means of achieving objectives.

Objective Tree Method – Procedure

Example - Testing shaft connections subjected to impulse loads

- The design problem was that of a machine to be used in testing shaft connections subjected to impulse loads.
- A typically vague requirement of a 'reliable and simple testing device' can be expanded into a much more detailed set of
- objectives
- 'Reliability' is expanded into
    - 'reliable operation‘
    - 'high safety'.
- 'Simple' is expanded into
    - 'simple production‘
    - 'good operating characteristics';
- In a case such as this, first attempts at expanding the list of objectives would probably produce statements at all levels of generality.
    - For example, asking 'What is meant by "simple"?' would have been likely to produce statements in random order such as,
    - 'easy maintenance',
    - 'small number of components',
    - 'simple assembly',
- Drawing these out in the hierarchical tree structure shows how they relate together.


Reliable and simple testing device
Reliable operation
Good reproducibility of torque-time curve
Low wear of moving parts
Low susceptibility to vibrations
Few disturbing factors
Tolerance of overloading
High safety
High mechanical safety
Few possible operator errors
Simple production
Simple component production
Small number of components
Low complexity of components
Many standard and bought-out parts
Simple assembly
Good operating characteristics
Easy maintenance
Easy handling
Quick exchange of test connections
Good accessibility of measuring systems

Steel Shaft Vs Carbon Fiber Shaft

Functional Analysis Method

Establishing Functions

Establishing Functions – Introduction

- **Aim** - The aim of the function analysis method is to establish the functions required, and the system boundary, of a new design.

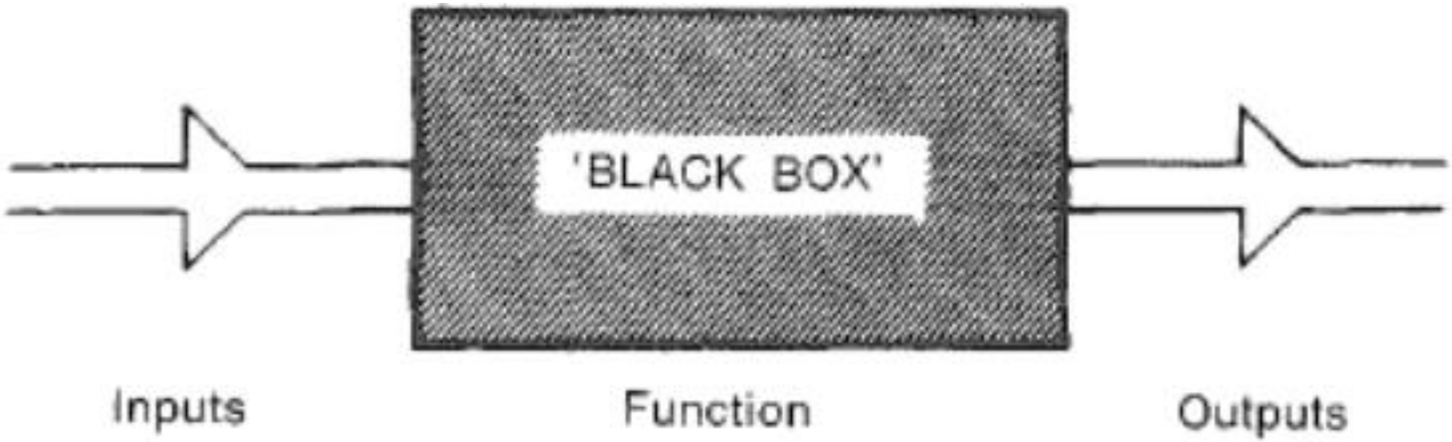
- **Essential Functions** - Essential functions are those that the device, product or system to be designed must satisfy, no matter what physical components might be used.
- **Boundary around subset of functions** - The problem level is decided by establishing a 'boundary' around a coherent subset of functions.

Functional Analysis Method
Step 1 – Black Box

- **System Boundary** - The 'system boundary' is the conceptual boundary that is used to define the function of the product or device.
  - Boundary is defined too narrowly – Minor design changes
  - Boundary is defined too broadly - Radical design rethinking.
- **I/O Definition** - Asking the clients or users for definitions of the fundamental purpose of the product or device, and asking about the required inputs and outputs: from where do the inputs come, what are the outputs for.
- **Black Box** - Express the overall function for the design in terms of the conversion of inputs into outputs

Functional Analysis Method
Step 1 – Black Box

- SISO
- SIMO
- MISO
- MIMO

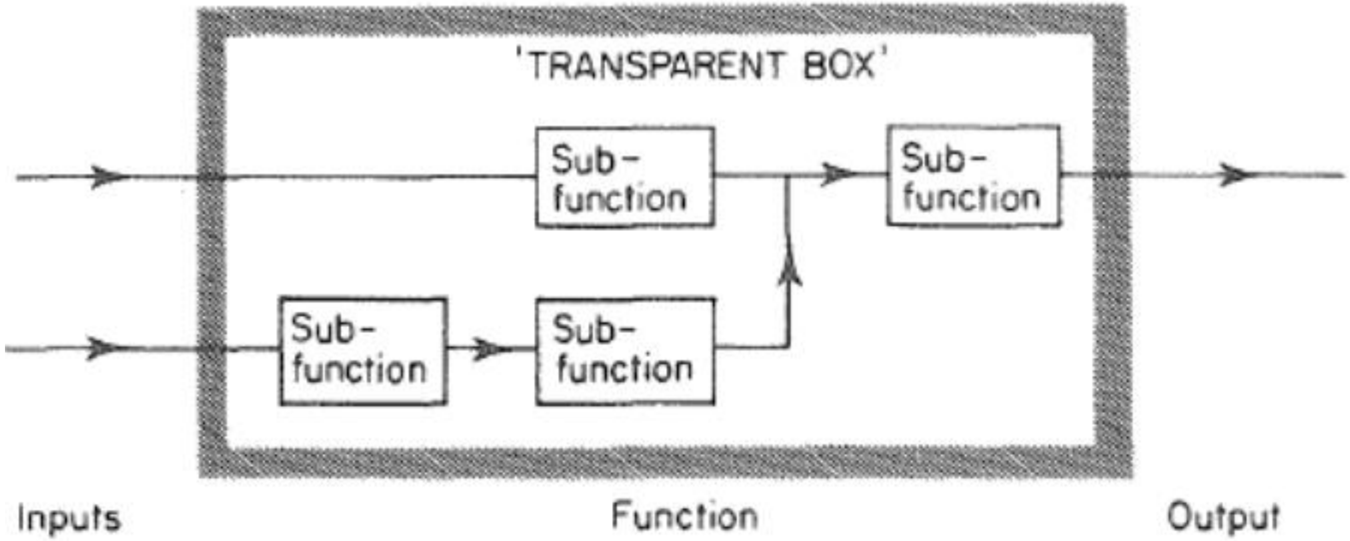


Functional Analysis Method
Step 2 – Transparent Box

- **Transparent Box** - Break down the overall function into a set of essential sub functions
- **No Systematic Way** - There is no really objective, systematic way of doing this; the analysis into sub functions may depend on factors such as:
  - The kinds of components available for specific tasks,
  - the necessary or preferred allocations of functions to machines or to human operators,
  - the designer's experience
- **Specifying Sub-Functions (Verb & Noun)** - It is helpful to ensure that they are all expressed in the same way. Each one should be a statement of a verb plus a noun
  - Example, 'amplify signal', 'count items', 'separate waste', 'reduce volume'.
- **Sub Function I/O** - Each sub function has its own input(s) and output(s), and compatibility between these should be checked.

Functional Analysis Method
Step 3 – Draw a block diagram

- MISO

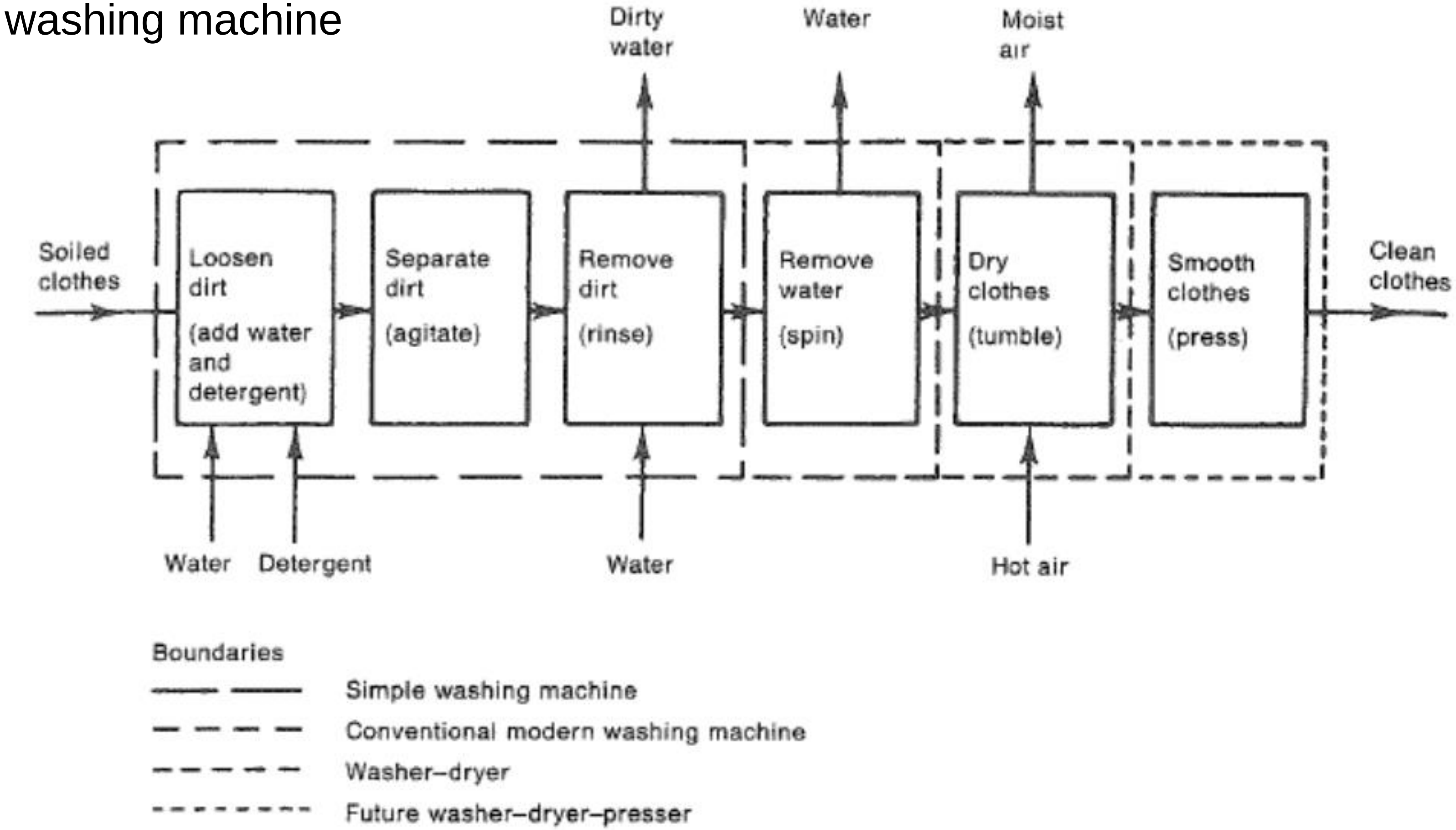


Functional Analysis Method
Step 4 - Draw the system boundary

- **Precise Extent and Location of the System Boundary** - In drawing the block diagram you will also need to make decisions about the precise extent and location of the system boundary.
  - Example, there can be no 'loose' inputs or outputs in the diagram except those that come from or go outside the system boundary.
- **Narrow Definition of Sub Functions** - The boundary now has to be narrowed again, after its earlier broadening during consideration of inputs, outputs and overall function.
- **Boundary Around Subset of the Functions** - The boundary has to be drawn around a subset of the functions that have been identified, in order to define a feasible product. It is also probable that this drawing of the system boundary is not something in which the designer has complete freedom - as likely as not, it will be a matter of management policy or client requirements.
- **Different Product and Solutions** - Many different system boundaries can be drawn, defining different products or solution types.

Functional Analysis Method
Step 4 - Draw the system boundary

Functional Analysis of a washing machine
Boundary Definition



Functional Analysis Method
Step 5 - Search for Components

- **Search for Components** - Search for appropriate components for performing the sub functions and their interactions
  - Example: , a 'component' might be defined as
    - A person who performs a certain task,
    - A mechanical component
    - An electronic device
- **Functions / Physical Devices** - The function analysis focuses on functions, and leaves the physical means of achieving those functions to later stage of the design process.

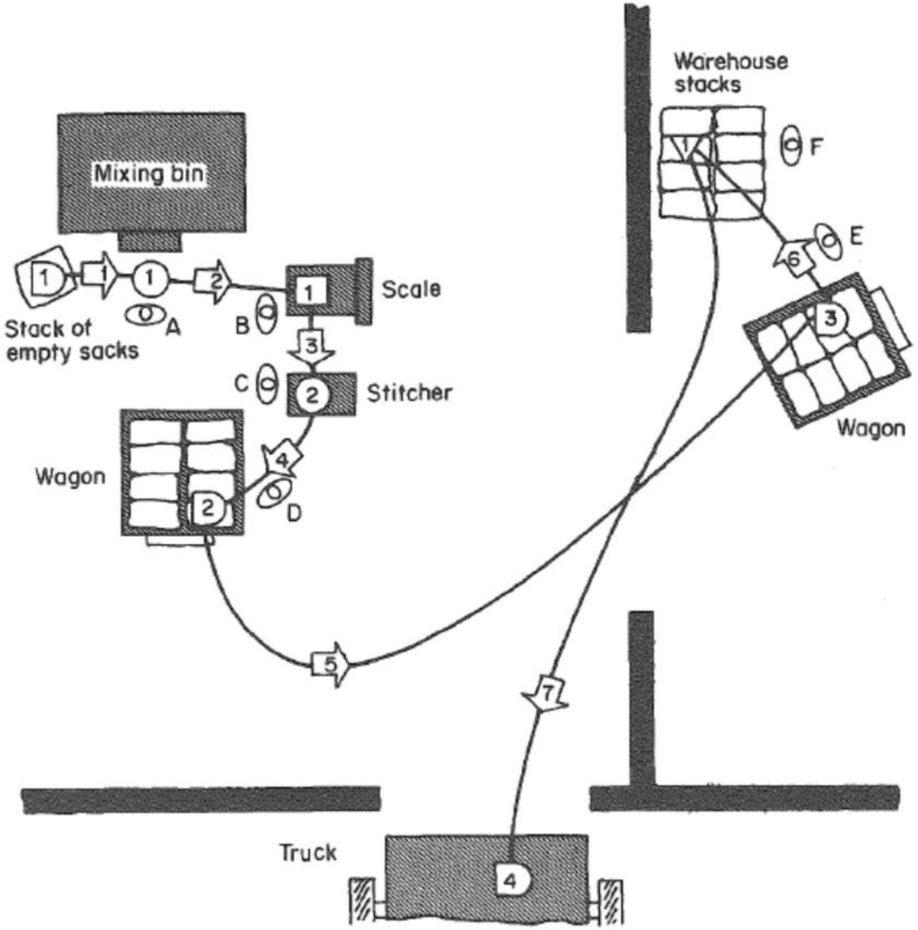
Functional Analysis Method
Step 5 - Search for Components

- Functions / Physical Devices

Functional Analysis Method
Example 1 – Feed Delivery System

- Factory where animal feedstuffs are bagged.
- The company wanted to try to reduce the relatively high costs of handling and storing the feedstuffs.
- A designer might tackle this task by searching for very direct ways in which each part of the existing process might be made more cost-effective.
- Broader formulation of the problem - the overall function - was represented in the following stages:
    1. Transfer of feed from mixing bin to bags stored in warehouse.
    2. Transfer of feed from mixing bin to bags loaded on truck
    3. Transfer of feed from mixing bin to consumers' storage bins.
    4. Transfer of feed ingredients from source to consumers' storagebins.

Functional Analysis Method
Example 1 – Feed Delivery System



□1	Stacked sacks await filling	②	Man C folds and stitches the top of the bag
⇨1	Man A lifts empty sack from stack and places it under spout for filling	⇨4	Man D takes the bag and loads it on wagon
①	Man A fills the 100-pound sack by gravity feed, manually controlling the rate of flow	⇨5	Loaded wagon is pushed to warehouse
⇨2	Man A hands the bag to man B	⇨6	Bags are stacked by men E and F
□1	Man B checks the weight and adds or removes material when necessary to adjust the weight to approximately 100 pounds	▽1	Bags are stored awaiting sale
⇨3	Man B hands the bag to man C	⇨7	Bags are loaded on waiting truck, two or three at a time by handtruck, then delivered to consumer

YouTube https://youtu.be/jTageuhPfAM

The Founder 'Speedy System‘ – The Tennis Court Scene – The Assembly Line

https://youtu.be/aIgmMXZ7008

McDonald's: The Origins of a Fast Food Empire

https://youtu.be/ocXP1pLeqLM

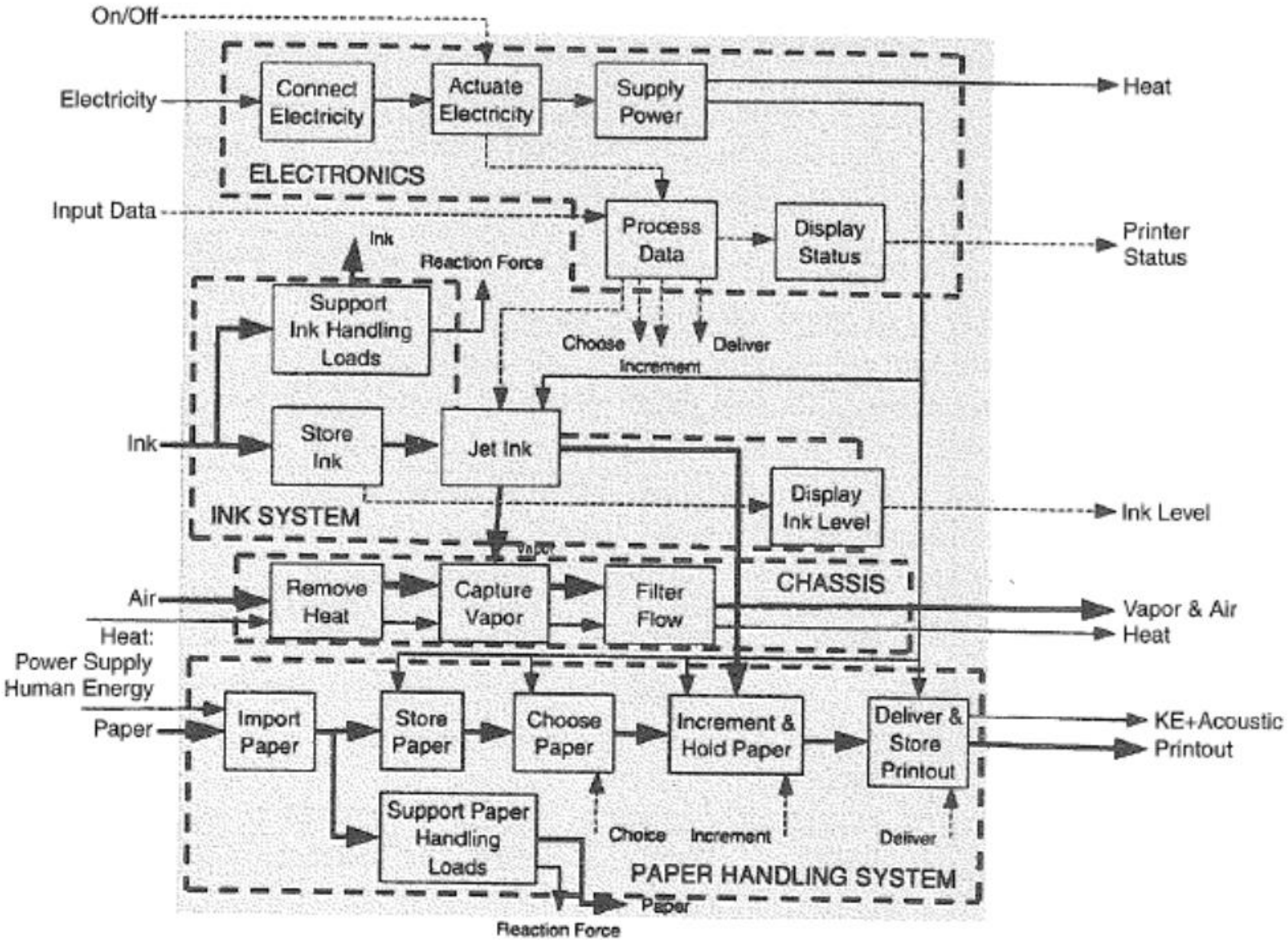
The Founder (2016) Persistence

One word... PERSISTENCE. Nothing in this world can take the place of good old persistence. Talent won't. Nothing's more common than unsuccessful men with talent. Genius won't. Unrecognized genius is practically a clich. Education won't. Why the world is full of educated fools. Persistence and determination alone are all powerful.

Functional Analysis Method
Example 2 – Feed Delivery System

- The following shows a function analysis for a desktop inkjet printer, with sub functions clustered. These clusters identify four primary modules for the printer:
  - Electronics,
  - Ink system (print cartridge),
  - Chassis and paper
  - Handling system.
- These modules depend, for the most part, on just one or two distinct connections between them.

Functional Analysis Method
Example 2 – Feed Delivery System



Functional Analysis Method – Summary

- **Aim** - The aim of the function analysis method is to establish the functions required, and the system boundary, of a new design.

1. Express the overall function for the design in terms of the conversion of inputs into outputs. The overall 'black box‘ function should be broad - widening the system boundary.

2. Break down the overall function into a set of essential sub functions. The sub functions comprise all the tasks that have to be performed inside the black box.

3. Draw a block diagram showing the interactions between sub functions. The black box is made 'transparent', so that the sub functions and their interconnections are clarified.

4. Draw the system boundary. The system boundary defines the functional limits for the product or device to be designed.

5. Search for appropriate components for performing the sub functions and their interactions. Many alternative components may be capable of performing the identified functions.

Performance Specification Method

Setting Requirements

Setting Requirements – Introduction

- **Aim** - Make an accurate specification of the performance required of a design solution.

- Design problems are always set within certain limits or constraints.
  - Examples For limits :
  - Cost
    - Selling Price - What the client is prepared to spend on a new machine
    - Buying Price - What customers may be paying as the purchase price of a product.
  - Geometry / Physics Attributes
    - Size - Acceptable size of the machine
    - Weight - Weight of a machine
  - Performance requirements
    - Engine's power rating
  - Legal requirements
  - Safety requirements

Setting Requirements – Introduction

- **Objectives and functions are not normally set in terms of precise limits** – Objectives and functions are statements of what a design must achieve or do, but they are not normally set in terms of precise limits, which is what a performance specification does.
- **Performance specification limits the acceptable solutions** - In setting limits to what has to be achieved by a design, a performance specification thereby limits the range of acceptable solutions.
- **Defined too narrowly – Eliminated acceptable solutions** - Because it therefore sets the designer's target range, it should not be defined too narrowly. If it is, then a lot of otherwise acceptable solutions might be eliminated unnecessarily.
- **Defined too broad - Vague / Inappropriate solutions** - A specification that is too broad or vague can leave the designer with little idea of the appropriate direction in which to aim. Specification limits that are set too wide can also lead to inappropriate solutions which then have to be changed or modified when it is found that they actually fall outside of acceptable limits.

Setting Requirements – Introduction

- **Accurate performance specification - Boundaries to the 'solution space‘** - Define the solution space - There are good reasons for putting some effort into an accurate performance specification early in the design process. Initially, it sets up some boundaries to the 'solution space' within which the designer must search.
- **Performance specification - Evaluating proposed solutions** - Later on in the design process, the performance specification can be used in evaluating proposed solutions, to check that they do fall within the acceptable boundaries.
- **Specification define required performance not product** - A specification defines the required performance, and not the required product. The method therefore emphasizes the performance that a design solution has to achieve, and not any particular physical components which may be means of achieving that performance.
- **Performance Specification Method**
  - Help in defining the design problem
  - Leaving the appropriate amount of freedom so that the designer has room to maneuver over the ways and means of achieving a satisfactory design solution.

Performance Specification Method
Step 1 – Consider Level of Generality

- **Consider Level of Generality** - Consider the different levels of generality of solution which might be applicable
- **Classification (high to low)** - A simple classification of types of level, from the most general down to the least, for a product might be:
  - Alternatives
  - Types
  - Features.
- Example: Domestic heating appliance
  - Alternatives: moveable appliances, fixed appliances, central heating with radiators, ducted warm air, solar heating
  - Types: radiators, convectors, fuel types
  - Features: heating element, switches, body casing

Performance Specification Method
Step 2 – Determine Level of Generality

- **Determine Level of Generality (Make a decision)** - Considering the different levels of generality might lead either to a broadening or a narrowing of initial product concepts or of the design brief. The second step of the method is therefore to make a decision on the appropriate level.
- **Client / Manager Decision -** Normally, the client, company management or customer decides the level at which the designer will operate.
- Example: Domestic heating appliance
  - Alternatives: Considered if an appliance manufacturer was proposing to diversify or broaden its activities into other aspects of domestic heating
  - Types: Considered when a new product was to be designed, to add to the existing range of appliances or to replace obsolete ones
  - Features: considered when making modifications to existing products.

Performance Specification Method
Step 3 – Performance Attributes

- **Identify the required performance attributes** – Any product or machine will have a set of attributes, and it is these which are specified in the performance specification.
  - Examples: comfort, portability durability, speed, cost safety.
- **Source for performance attributes - Objectives tree / Functions Analysis** - Performance attributes are usually similar to, or derived from, the design objectives and functions. So if you have already prepared an objectives tree or a functions analysis, these are likely to be the source of your initial list of performance attributes.
- **Listing performance attributes independent of any particular solution** - A most important aspect to bear in mind when listing performance attributes is that they should be stated in a way which is independent of any particular solution. Statements of attributes made by clients or customers are often couched in terms of solutions, because they value some performance aspect which is embodied in the solution but they have not separated the attribute from a particular embodiment. Such solution-based rather than performance-based statements are usually unnecessarily restrictive of solution concepts.
- **Demands / Wishes** - The final list of performance attributes contains all the conditions that a design proposal should satisfy. However, it may become necessary to distinguish within this list between those attributes or requirements that are 'demands' and those that are 'wishes'. Demands are requirements that must be met, whereas wishes are those that the client, customer or designer would like to meet if possible.

Performance Specification Method
Step 4 – State precise performance requirements

- **State precise performance requirements for each attribute (must do; not must be)** - A specification says what a product must do; not what it must be.
- **Need for research** - this may well require some careful research- it is not adequate simply to guess at performance requirements, nor just to take them from an existing solution type.
- **Quantified terms** - Wherever possible, a performance requirement should be expressed in quantified terms.
    - Example,
        - Maximum weight
            - Yes - Numerical Value
            - No - 'lightweight'.
        - Safety requirement - Escape from a vehicle-
            - Yes - Maximum time allowable for escape in an emergency
            - No - 'rapidly' or 'readily'.
        - Tolerance
            - Yes – Range
            - No – Specific value

Performance Specification Method Example – Fuel Gauge

- **Lowest level of generality (Client)** - The problem was formulated by the client at the lowest level of generality
- **General formulation of the problem statement**:

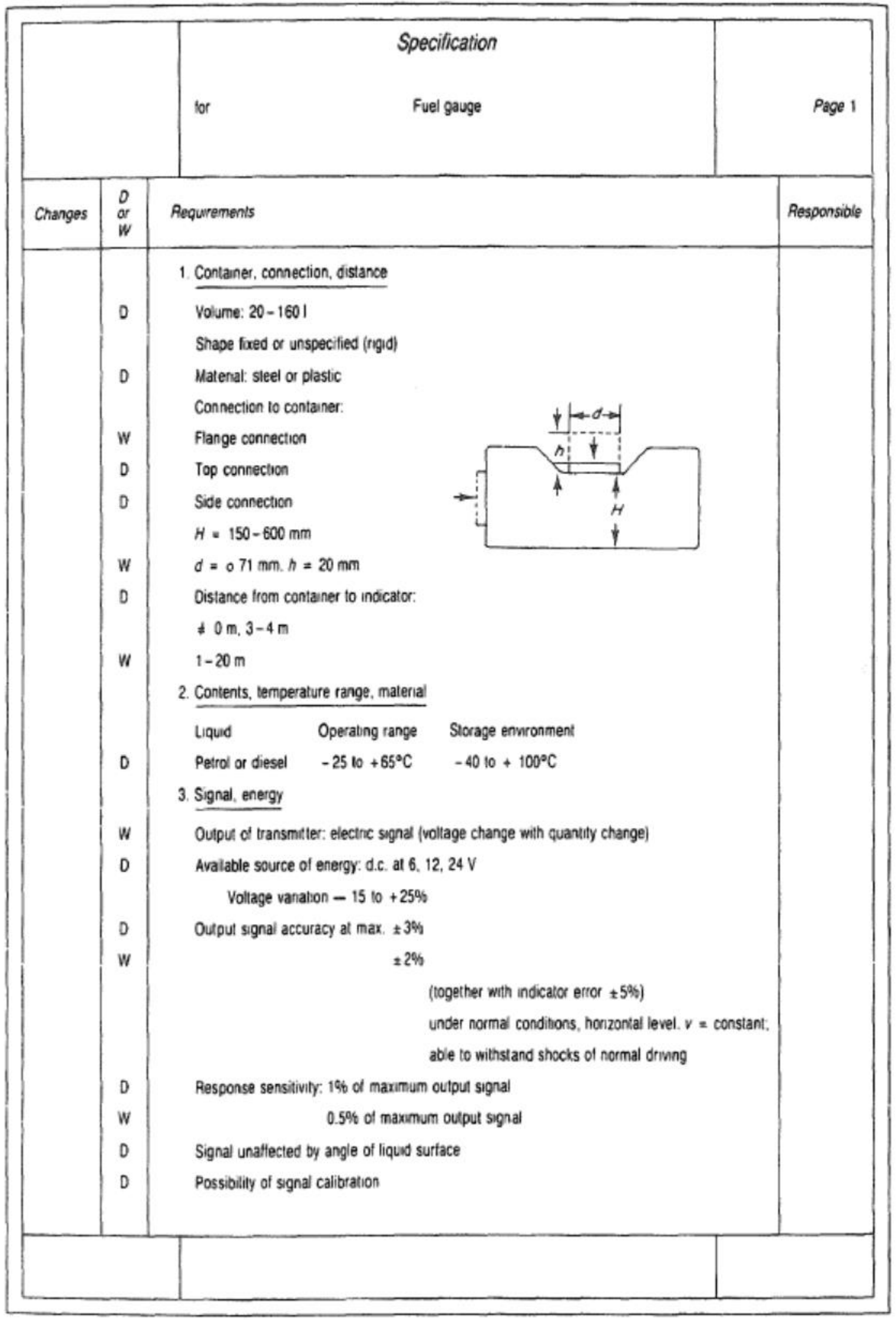
  The design of a particular type of fuel gauge for use in motor vehicles. A gauge to measure continuously changing quantities of liquid in containers of unspecified size and shape, and to indicate the measurement at various distances from the containers.

Performance Specification Method Example – Fuel Gauge

- **List of Attributes**
- Suitable for containers (fuel tanks) of
  - various volumes
  - various shapes
  - various heights
  - various materials
- Connection to top or side of container.
- Operates at various distances from container.
- Measures petrol or diesel liquid.
- Accurate signal.
- Reliable operation.

- **Problem statement**:

  The design of a particular type of fuel gauge for use in motor vehicles. A gauge to measure continuously changing quantities of liquid in containers of unspecified size and shape, and to indicate the measurement at various distances from the containers.

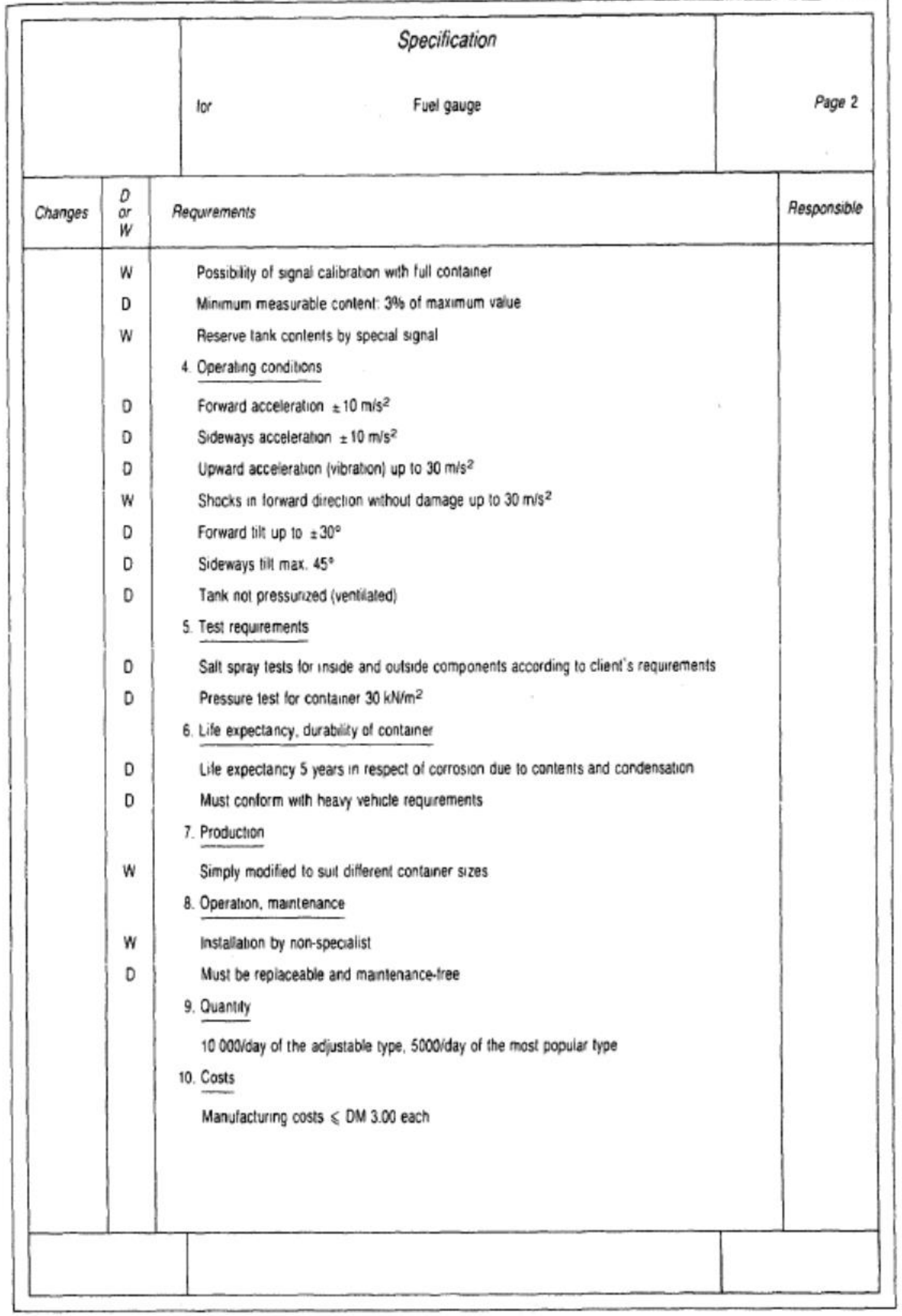


Specification

for Fuel gauge

Page 1

Changes	*D or W*	*Requirements*	*Responsible*
		1. Container, connection, distance	
	D	Volume: 20 – 160 l	
		Shape fixed or unspecified (rigid)	
	D	Material: steel or plastic	
		Connection to container:	
	W	Flange connection	
	D	Top connection	
	D	Side connection	
		H = 150 – 600 mm	
	W	d = ⌀ 71 mm, h = 20 mm	
	D	Distance from container to indicator:	
		≠ 0 m, 3 – 4 m	
	W	1 – 20 m	
		2. Contents, temperature range, material	
		Liquid — Operating range — Storage environment	
	D	Petrol or diesel — −25 to +65°C — −40 to + 100°C	
		3. Signal, energy	
	W	Output of transmitter: electric signal (voltage change with quantity change)	
	D	Available source of energy: d.c. at 6, 12, 24 V	
		Voltage variation − 15 to +25%	
	D	Output signal accuracy at max. ±3%	
	W	±2%	
		(together with indicator error ±5%)	
		under normal conditions, horizontal level. v = constant;	
		able to withstand shocks of normal driving	
	D	Response sensitivity: 1% of maximum output signal	
	W	0.5% of maximum output signal	
	D	Signal unaffected by angle of liquid surface	
	D	Possibility of signal calibration	



Specification

for Fuel gauge

Page 2

Changes	*D or W*	*Requirements*	*Responsible*
	W	Possibility of signal calibration with full container	
	D	Minimum measurable content: 3% of maximum value	
	W	Reserve tank contents by special signal	
		4. Operating conditions	
	D	Forward acceleration ±10 m/s²	
	D	Sideways acceleration ±10 m/s²	
	D	Upward acceleration (vibration) up to 30 m/s²	
	W	Shocks in forward direction without damage up to 30 m/s²	
	D	Forward tilt up to ±30°	
	D	Sideways tilt max. 45°	
	D	Tank not pressurized (ventilated)	
		5. Test requirements	
	D	Salt spray tests for inside and outside components according to client's requirements	
	D	Pressure test for container 30 kN/m²	
		6. Life expectancy, durability of container	
	D	Life expectancy 5 years in respect of corrosion due to contents and condensation	
	D	Must conform with heavy vehicle requirements	
		7. Production	
	W	Simply modified to suit different container sizes	
		8. Operation, maintenance	
	W	Installation by non-specialist	
	D	Must be replaceable and maintenance-free	
		9. Quantity	
		10 000/day of the adjustable type, 5000/day of the most popular type	
		10. Costs	
		Manufacturing costs ⩽ DM 3.00 each	

Performance Specification Method - Summary

Aim - Make an accurate specification of the performance required of a design solution.

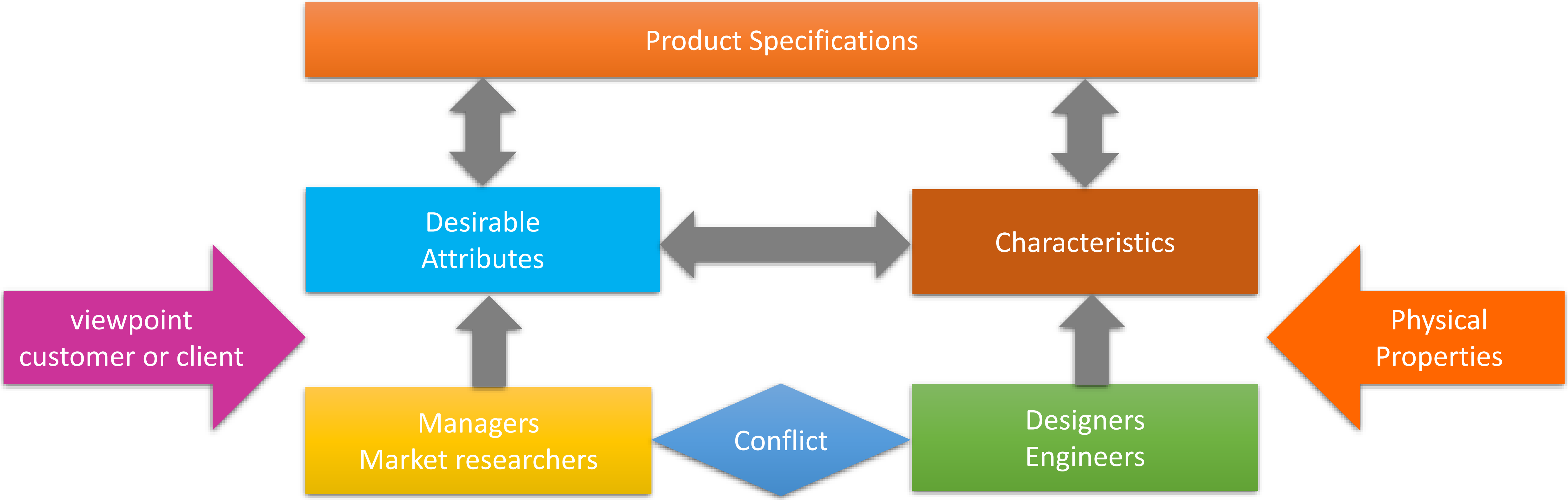
The procedure is as follows:

1. Consider the different levels of generality of solution which might be applicable. There might be a choice between
    - product alternatives
    - product types
    - product features.
2. Determine the level of generality at which to operate. This decision is usually made by the client. The higher the level of generality, the more freedom the designer has.
3. Identify the required performance attributes. Attributes should be stated in terms which are independent of any particular solution.
4. State succinct and precise performance requirements for each attribute. Wherever possible, specifications should be in quantified terms, and identify ranges between limits.

Quality Function Deployment (QFD) Method

Determining Characteristics

Determining Characteristics – Introduction



Product Specifications

Desirable Attributes

Characteristics

viewpoint customer or client

Physical Properties

Managers Market researchers

Conflict

Designers Engineers

Determining Characteristics – Introduction

- **QFD** - Quality Function Deployment method
- **Product Design Philosophy** - 'listening to the voice of the customer
- **Customer who buys a product is the most important person in determining the commercial success of a product** - The QFD method recognizes that the person who buys (or who most influences the buying decision for) a product is the most important person in determining the commercial success of a product.
  - **Commercial Success** - If customers buy it
  - **Commercial Failure** - If customers do not buy it, then the product – however 'well designed' it may be - will be a commercial failure.

Determining Characteristics – Introduction

- **QFD Approach**
- ‘The voice of the customer' has priority in determining the product's attributes.
- **Identify the Customers** - Identify who the customers are
- **Listen to the Customers** Listen carefully to what they say
- **Determine Engineering Characteristics** - Determine the product's engineering characteristics in the light of this.

Quality Function Deployment Method
Step 1: Identify customer requirements in terms of product attributes

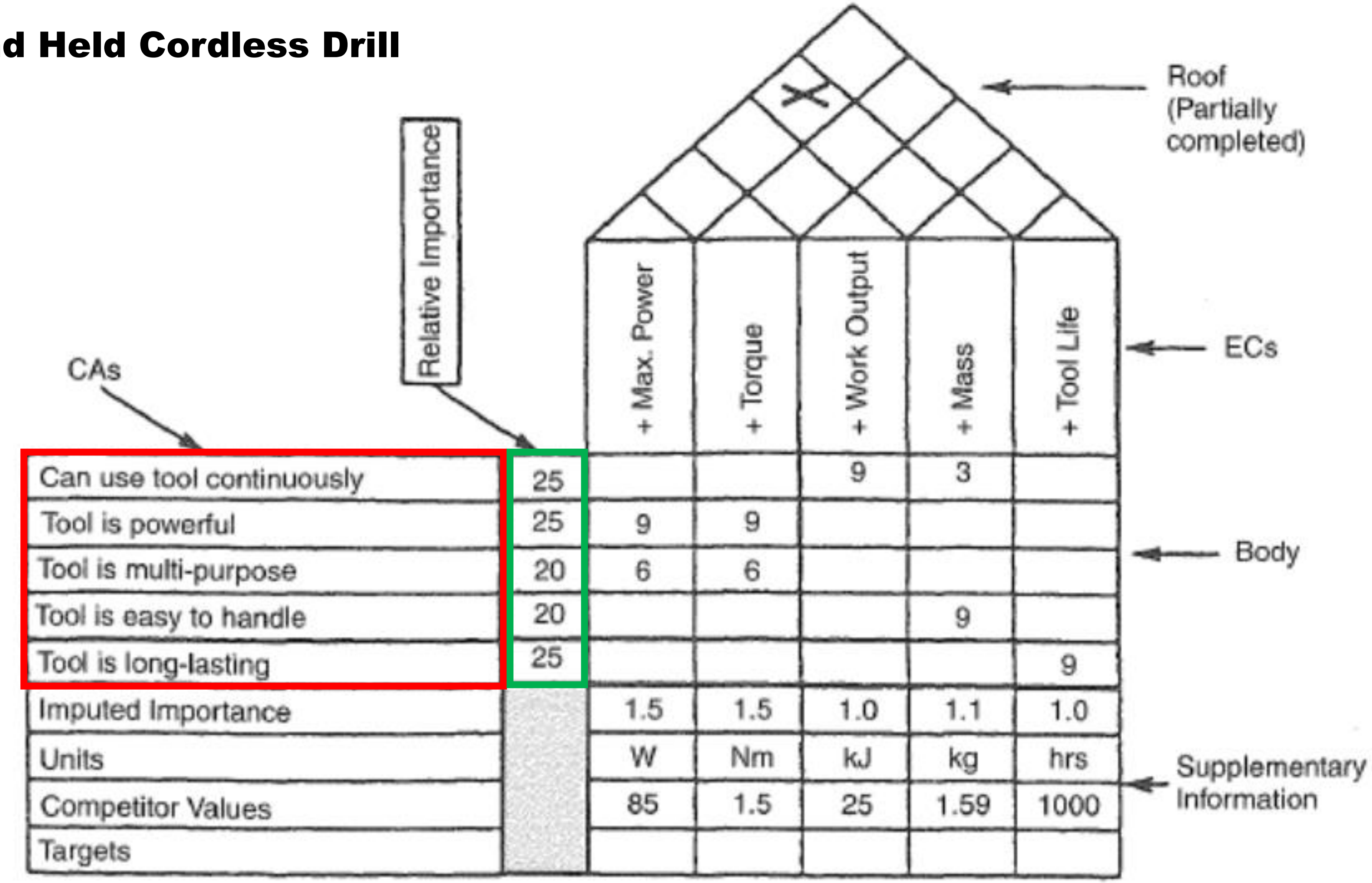
- **Research Methods**
  - Focus groups
  - Questionnaires
- **Translation Customers Statements into Requirements (Attributes & Characteristics)** - Interpret the more general statements by customers e.g 'It's easy to use' to 'I don't like the color'. into more precise statements of requirements

Quality Function Deployment Method
Step 2: Determine the relative importance of the attributes

- **Attributes' Importance** - Not all the identified product attributes will be equally important to customers.
  - Example, 'easy to use' may be regarded as much more important than' easy to maintain'.

- **Ranking Attributes** – Allocation of relative 'weights' to the set of customer-specified product attributes. Normally, a percentage value is set for each attribute, i.e. the weights for the complete set of attributes add up to a total of 100.

Example- Hand Held Cordless Drill

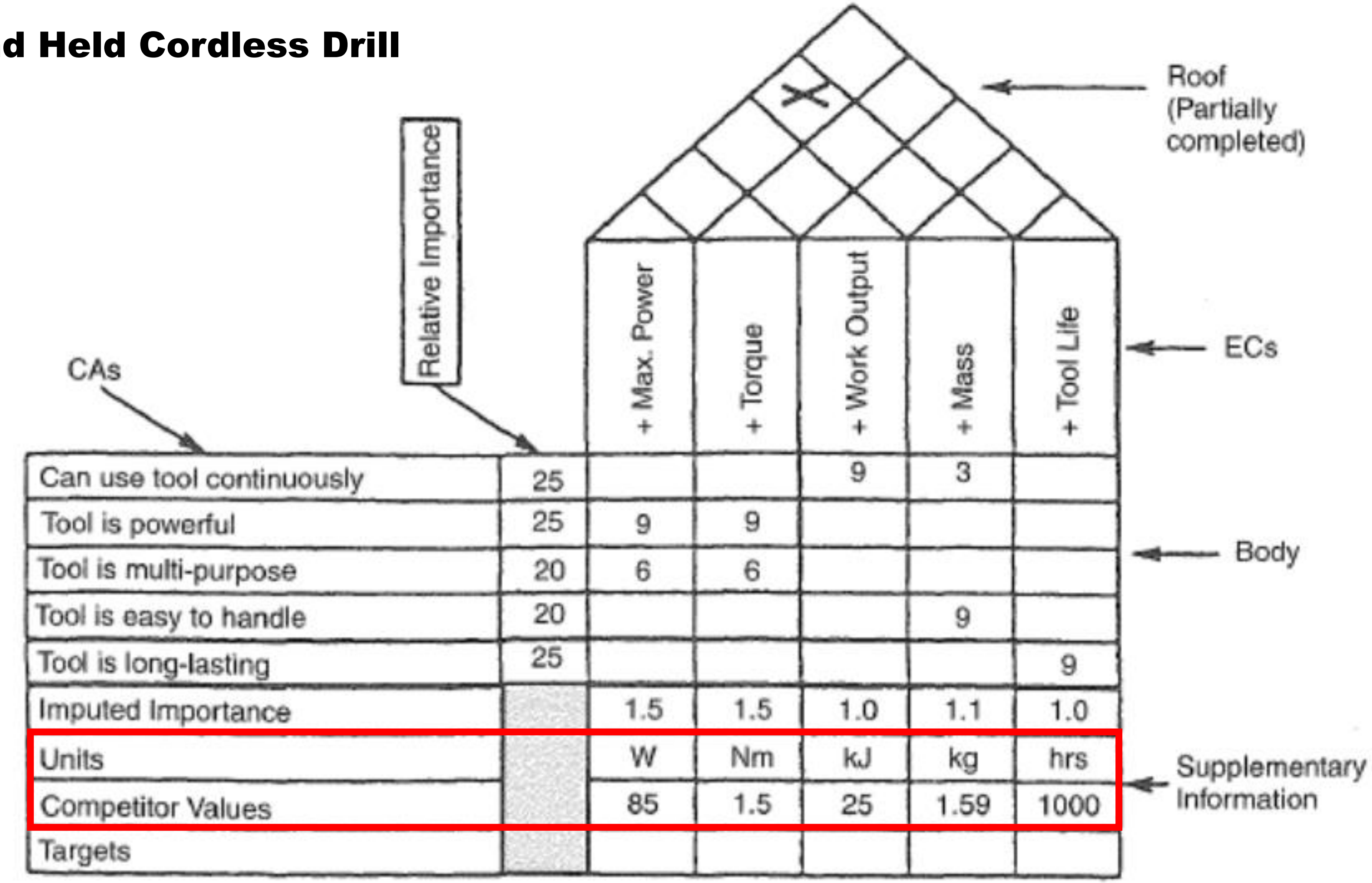


	Relative Importance	+ Max. Power	+ Torque	+ Work Output	+ Mass	+ Tool Life
Can use tool continuously	25			9	3	
Tool is powerful	25	9	9			
Tool is multi-purpose	20	6	6			
Tool is easy to handle	20				9	
Tool is long-lasting	25					9
Imputed Importance		1.5	1.5	1.0	1.1	1.0
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method
Step 3: Evaluate the attributes of competing products

- **Analyzing Competitive Products** - In a competitive market, the design team has ensure that its product will satisfy customer requirements better than the competitor products. The performance of the competition is therefore analyzed, particularly with regard to those product attributes that are weighted high in relative importance.
- **Designing New Improvement and Maintain Good Features** - In this step in the procedure not only highlights where improvements to the design team's product may be necessary, but also where this current product already has advantages over the competition, which should be maintained.

Example- Hand Held Cordless Drill



Roof (Partially completed)

ECs

Body

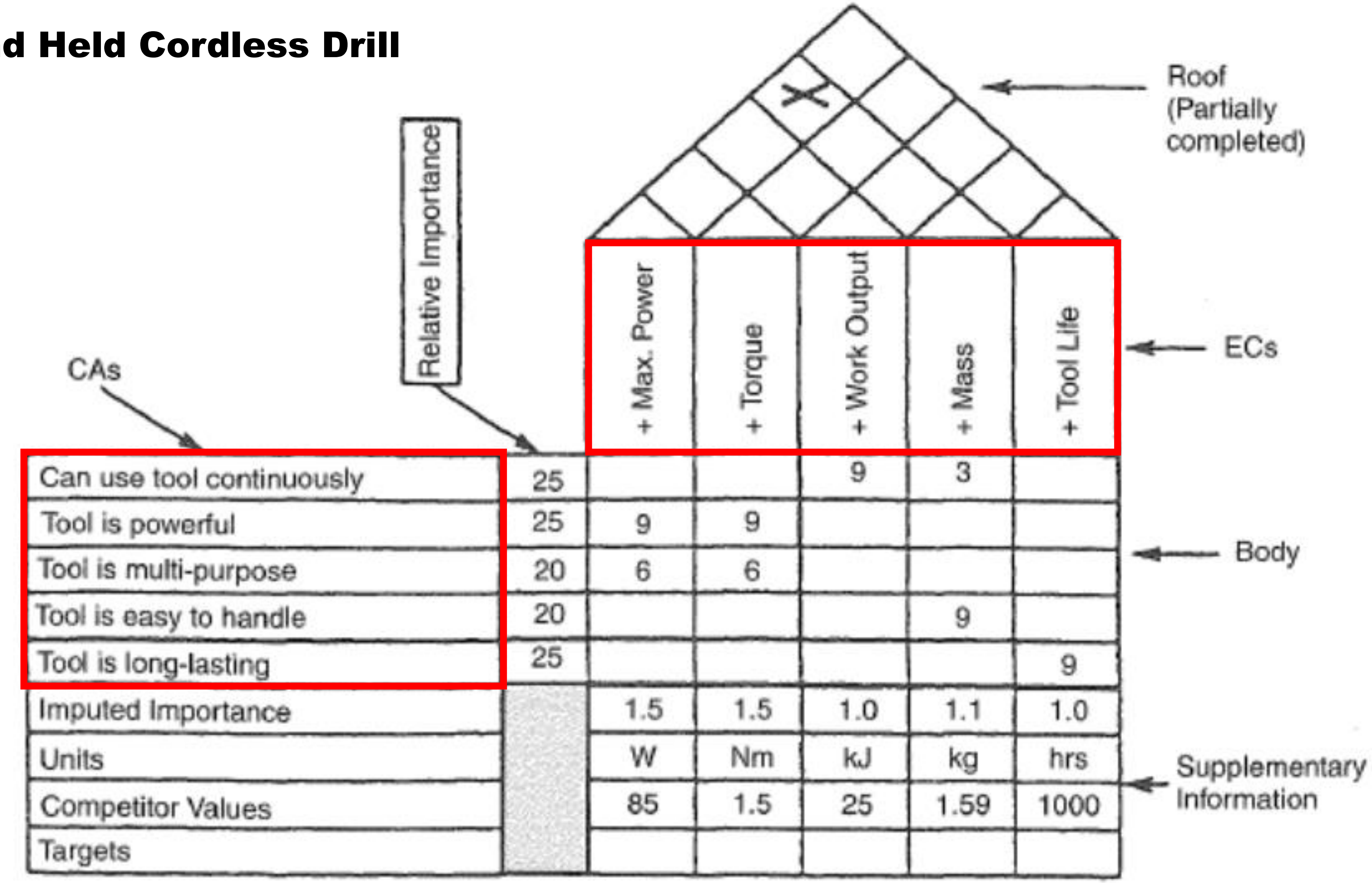
Supplementary Information

CAs	Relative Importance	+ Max. Power	+ Torque	+ Work Output	+ Mass	+ Tool Life
Can use tool continuously	25			9	3	
Tool is powerful	25	9	9			
Tool is multi-purpose	20	6	6			
Tool is easy to handle	20				9	
Tool is long-lasting	25					9
Imputed Importance		1.5	1.5	1.0	1.1	1.0
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method
Step 4: Draw a matrix of product attributes against engineering characteristics

- **Customers Provide Attributes** - Customers are not experts and therefore cannot usually specify their requirements in terms of the product's engineering characteristics that influence those requirements.
  - Example – Customers expect 'responsiveness' feels from a car
- **Engineering Team / Designers Provide Engineering Characteristics** - the design team to identify those engineering characteristics of their product that satisfy or influence in any way the customer requirements.
  - Example – Design team specify engineering characteristics such as overall weight of a car, and engine torque that will influence its 'responsiveness'.

Example- Hand Held Cordless Drill



	Relative Importance	+ Max. Power	+ Torque	+ Work Output	+ Mass	+ Tool Life
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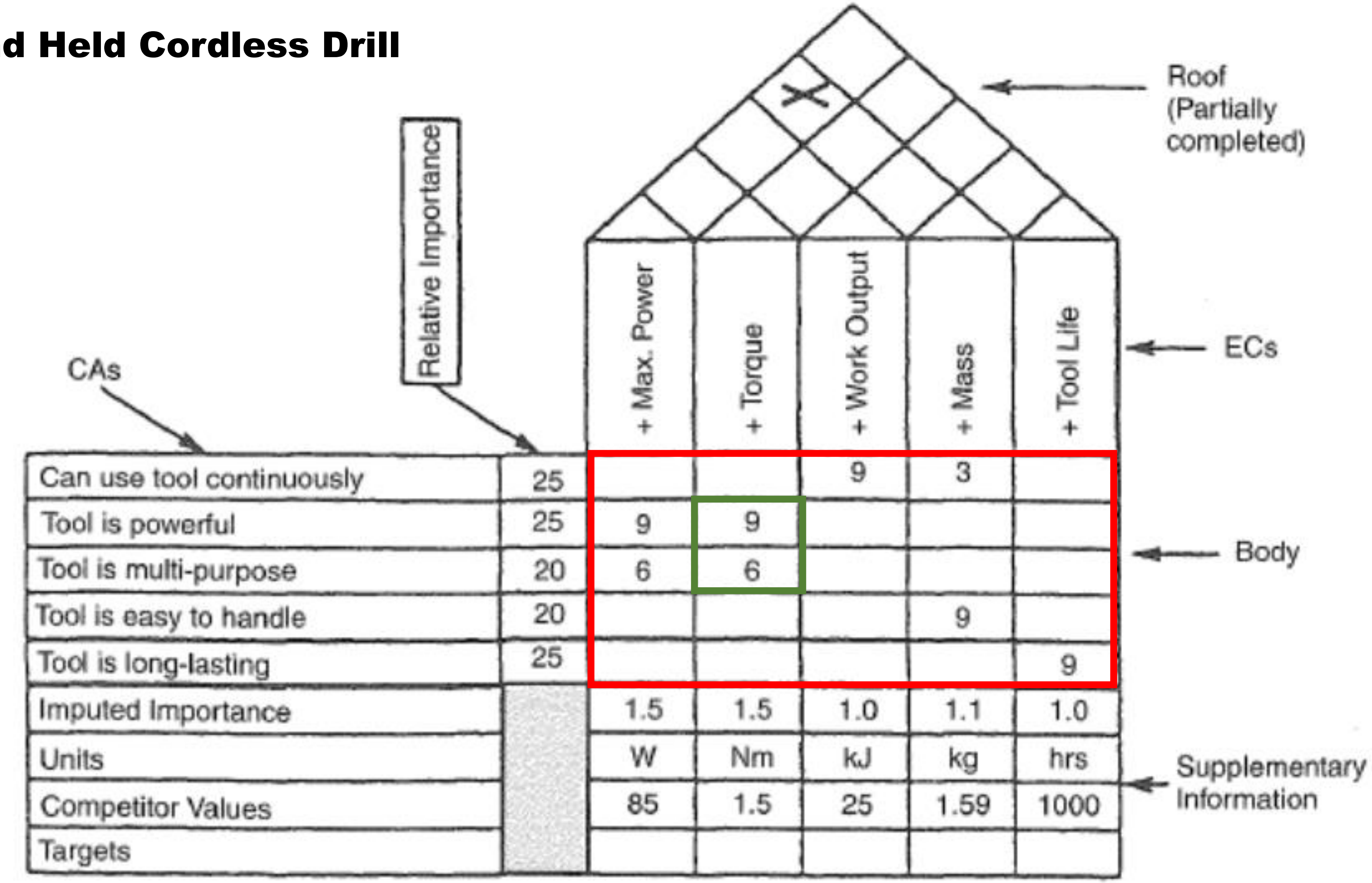
Tool is easy to handle	20				9	
Tool is long-lasting	25					9
Imputed Importance		1.5	1.5	1.0	1.1	1.0
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method
Step 5: Identify the relationships between engineering characteristics and product attributes

- **Identify cases where engineering characteristic influences** - product attribute By checking through the cells of the matrix it is possible to identify where any engineering characteristic influences any product attribute.
- **Identify Numerically the strength of that relationship** - The design team works methodically through the matrix, and records in the matrix cells wherever a relationship occurs, and the strength of that relationship. Sometimes numbers are used to represent the strength of the relationship

Example- Hand Held Cordless Drill



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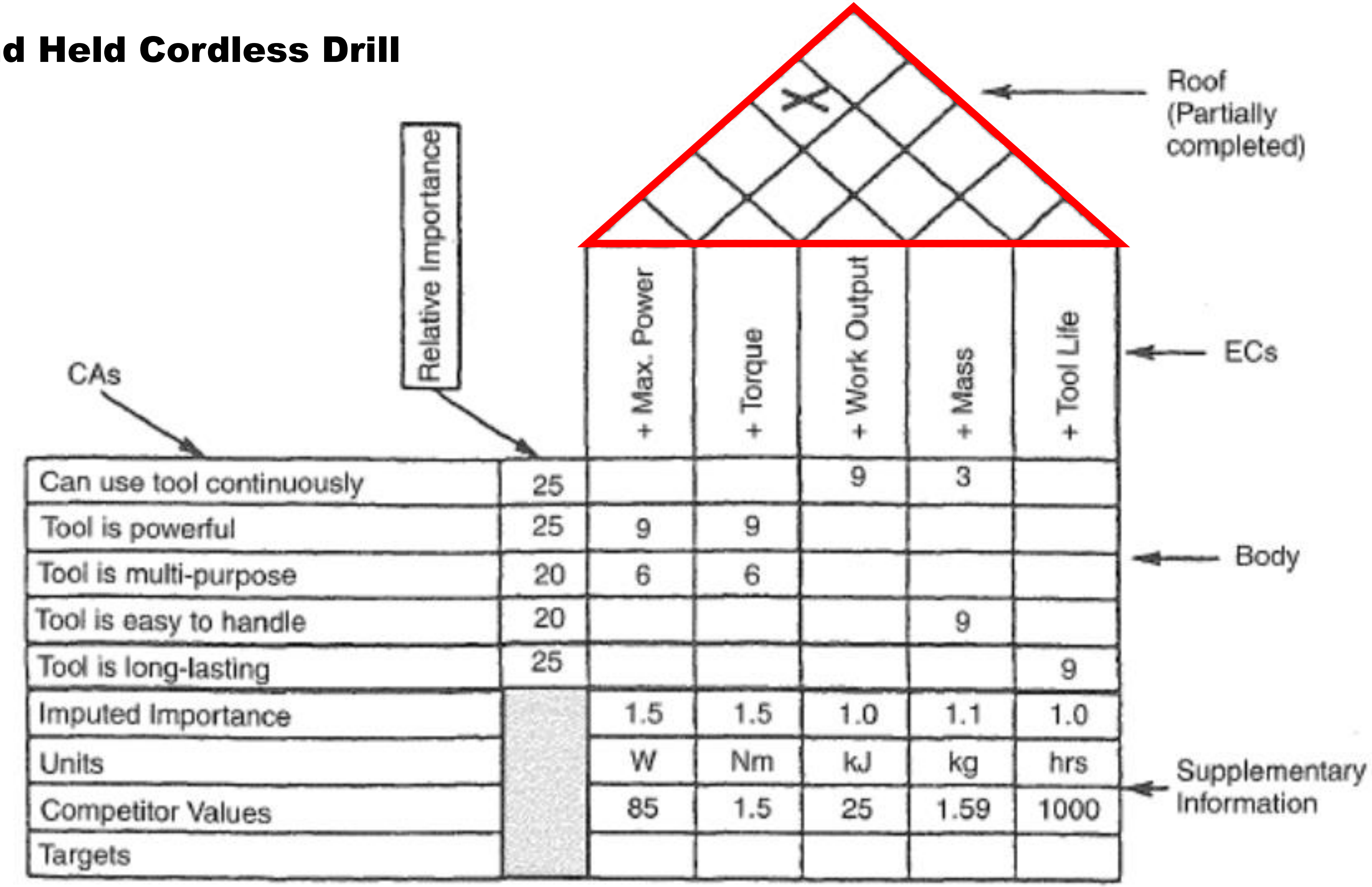
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method
Step 6: Identify any relevant interactions between engineering characteristics

- **Interactions between engineering characteristics and themselves** - It is often the case that engineering characteristics interact with each other, particularly in terms of their influence on customers‘ perceptions of the product.
    - Example, a more powerful engine is also likely to be heavier, thus increasing the vehicle weight, and so not necessarily increasing its perceived 'responsiveness'.
    -
- **Roof Matrix** - Working through the 'roof' matrix enables a systematic check to be made of the interactions between the engineering characteristics, and whether these interactions are negative or positive. However, many assumptions may have to be made about the final design when completing the 'roof' matrix, and it should be remembered that changes in the design concept may result in changes in these interactions.

Example- Hand Held Cordless Drill



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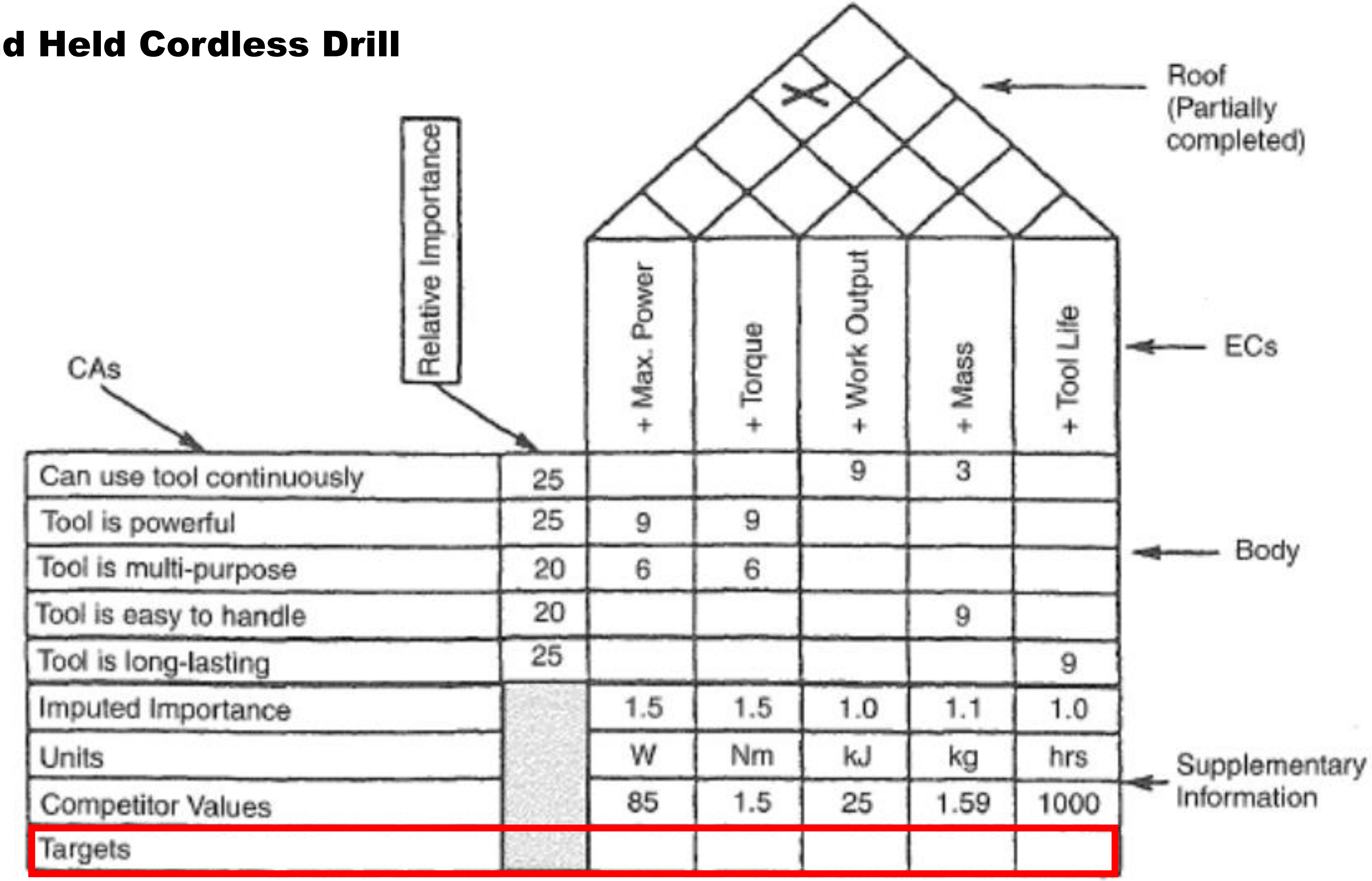
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method
Step 7: Set target figures to be achieved for the engineering characteristics

- **Set targets values** - The design team set targets for themselves which would be better than the competition. Sometimes it may be necessary to conduct trials with customers in order to determine what would be acceptable target figures to set. This is similar to determining values in a performance specification.

Example- Hand Held Cordless Drill



Roof (Partially completed)

ECs

Body

Supplementary Information

	Relative Importance	+ Max. Power	+ Torque	+ Work Output	+ Mass	+ Tool Life
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Imputed Importance		1.5	1.5	1.0	1.1	1.0
Units		W	Nm	kJ	kg	hrs
Competitor Values		85	1.5	25	1.59	1000
Targets						

Quality Function Deployment Method– Summary

Aim - Set targets to be achieved for the engineering characteristics of a product, such that they satisfy customer requirements.

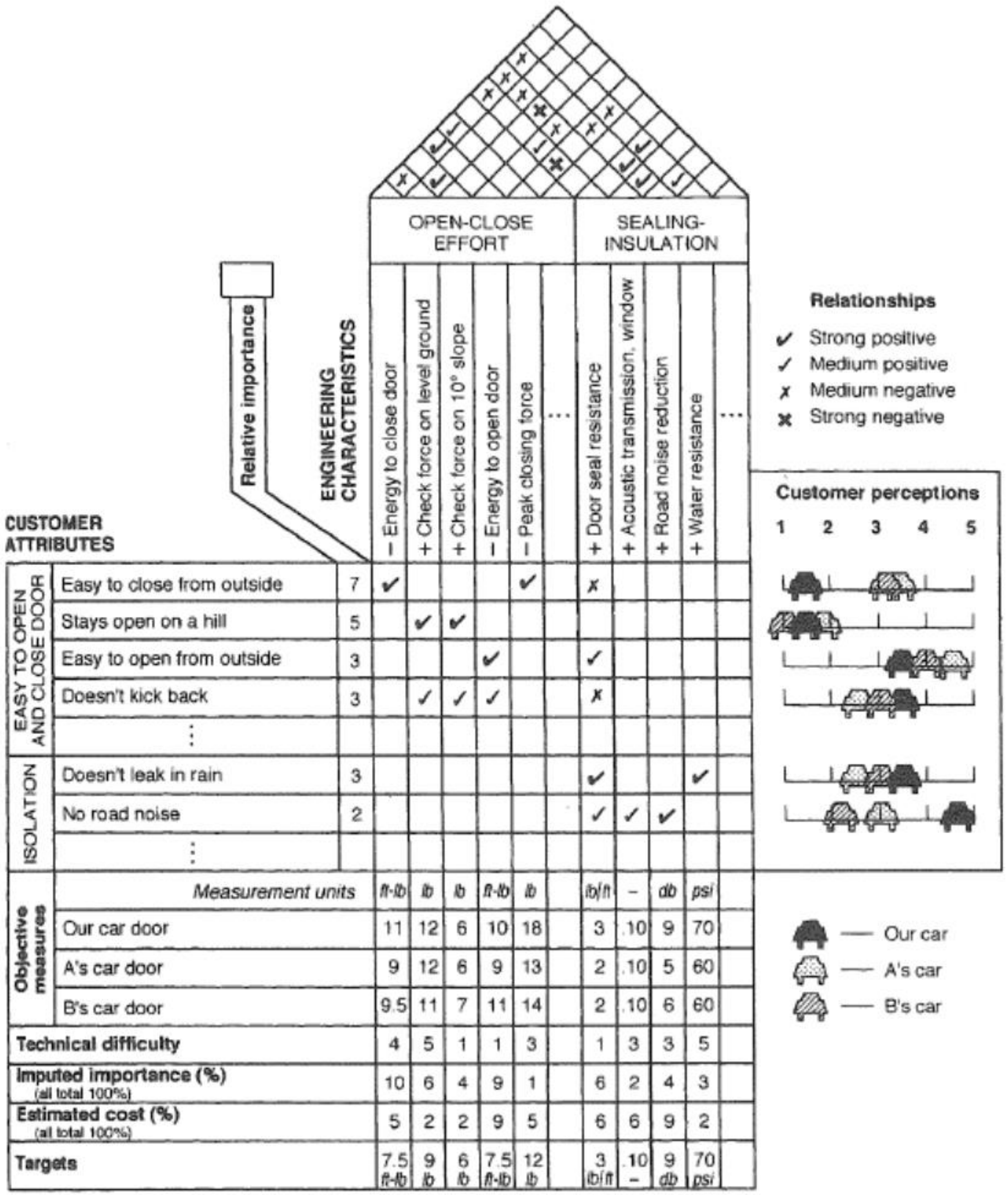
The procedure is as follows:

1. Identify customer requirements in terms of product attributes. It is important that 'the voice of the customer' is recognized, and that customer requirements are not subject to 'reinterpretation‘ by the design team.
2. Determine the relative importance of the attributes. Techniques of rank-ordering or points-allocation can be used to help determine the relative weights that should be attached to the various attributes. Percentage weights are normally used.
3. Evaluate the attributes of competing products. Performance scores for competing products and the design team's own product (if a version of it already exists) should be listed against the set of customer requirements.
4. Draw a matrix of product attributes against engineering characteristics. Include all the engineering characteristics that influence any of the product attributes and ensure that they are expressed in measurable units.
5. Identify the relationships between engineering characteristics and product attributes. The strength of the relationships can be indicated either by symbols or numbers; using numbers has some advantages, but can introduce a spurious accuracy.
6. Identify any relevant interactions between engineering characteristics. The 'roof' matrix of the 'house of quality' provides this check, but may be dependent upon changes in the design concept.
7. Set target figures to be achieved for the engineering characteristics. Use information from competitor products or from trials with customers.

https://youtu.be/m2n0W1ycolY

House of Quality / QFD (Quality Function Deployment) Intro (Example – Water Filter)

Quality Function Deployment Method– Example: Car Door

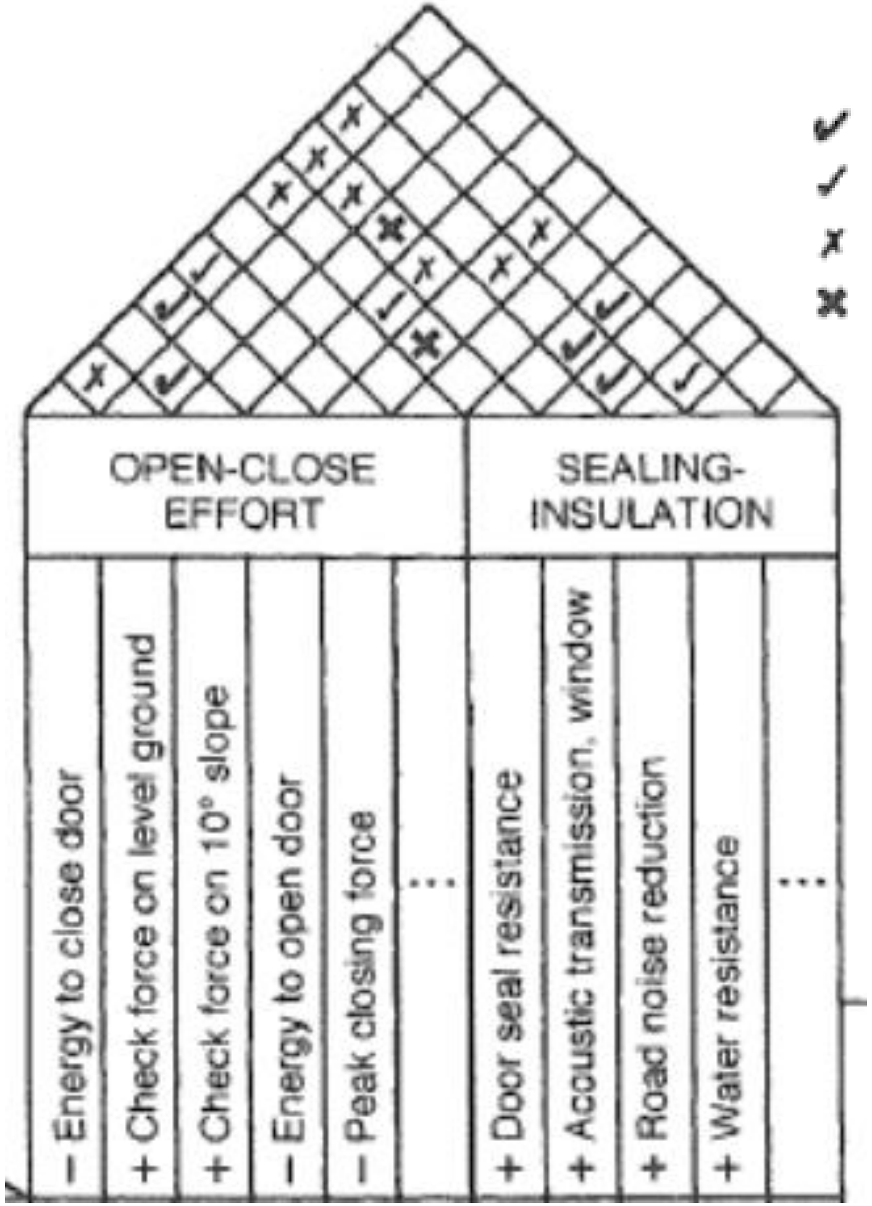


			OPEN-CLOSE EFFORT						SEALING-INSULATION				
		Relative importance	− Energy to close door	+ Check force on level ground	+ Check force on 10° slope	− Energy to open door	− Peak closing force	⋯	+ Door seal resistance	+ Acoustic transmission, window	+ Road noise reduction	+ Water resistance	⋯
EASY TO OPEN AND CLOSE DOOR	Easy to close from outside	7	✔				✔		✗				
	Stays open on a hill	5		✔	✔								
	Easy to open from outside	3				✔			✓				
	Doesn't kick back	3		✓	✓	✓			✗				
	⋮												
ISOLATION	Doesn't leak in rain	3							✔			✔	
	No road noise	2							✓	✓	✔		
	⋮												
Objective measures	*Measurement units*		*ft-lb*	*lb*	*lb*	*ft-lb*	*lb*		*lb/ft*	–	*db*	*psi*	
	Our car door		11	12	6	10	18		3	.10	9	70	
	A's car door		9	12	6	9	13		2	.10	5	60	
	B's car door		9.5	11	7	11	14		2	.10	6	60	
Technical difficulty			4	5	1	1	3		1	3	3	5	
Imputed importance (%) (all total 100%)			10	6	4	9	1		6	2	4	3	
Estimated cost (%) (all total 100%)			5	2	2	9	5		6	6	9	2	
Targets			7.5 *ft-lb*	9 *lb*	6 *lb*	7.5 *ft-lb*	12 *lb*		3 *lb/ft*	.10 –	9 *db*	70 *psi*	

Relationships

- ✔ Strong positive
- ✓ Medium positive
- ✗ Medium negative
- ✖ Strong negative

- Our car
- A's car
- B's car



Relationships

- ✔ Strong positive
- ✓ Medium positive
- ✗ Medium negative
- ✖ Strong negative

UCLA

References

- Books
    - Chapter 5 - Explicate Problem
      An Introduction to Design Science
      Authors: Johannesson, Paul, Perjons, Erik
    - Chapters 6,7,8,9
      Nigel Cross, Engineering Design Methods, Wiley

- Websites
    - Quality Function Deployment in Continuous Improvement

- Videos
    - Quality Function Deployment (QFD) and House of Quality – Car
    - Quality Function Deployment (QFD) and House of Quality – Water Filter