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Implementing Cognitive Work Analysis to Support Early Phases of Sociotechnical System Development

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Systems and Systems Engineering

A system is a set of integrated components working toward a common goal

This common goal is reflected in the user requirements

Systems engineering is often applied to the development of complex systems

Systems engineering is a systematic and multidisciplinary endeavor

Project success require a common understanding of requirements

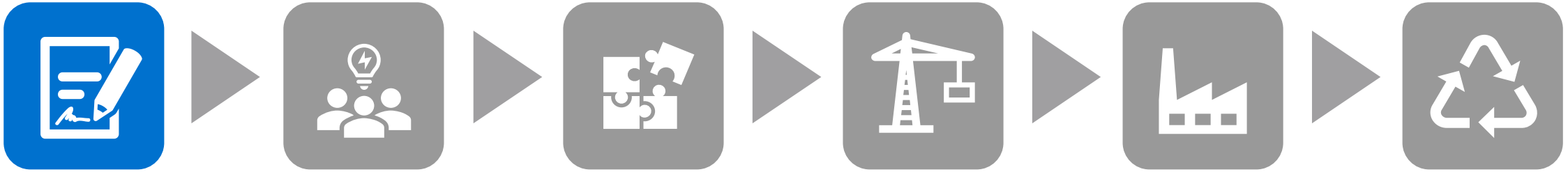
New Technology Introduction

New technology evolves user requirements

- This may have unforeseen and counter-intuitive consequences
- These may include both valuable and unacceptable properties
- The ability to predict challenges to technology adoption is vital
- The classic reductionist approach of SE in not conducive to this

User Requirements

User requirements is the golden thread through a project



- Design freedom is at its highest early on in projects
- Capturing a complete set of requirements early on is key
- Cognitive work analysis models capture the relationship between technological functions and requirements

Development of Complex Sociotechnical Systems

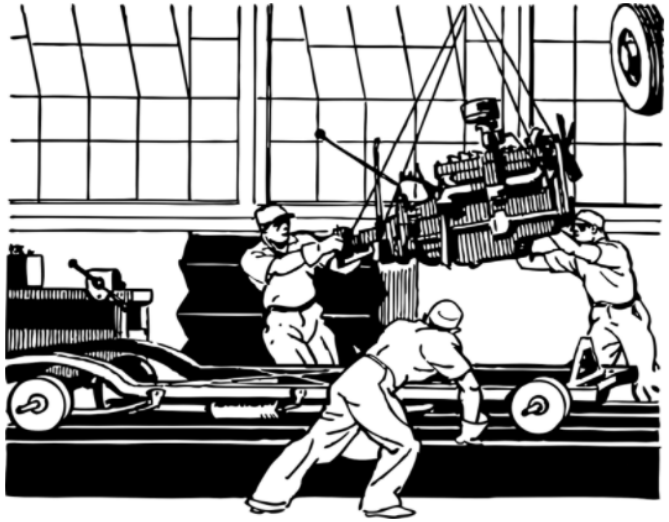
Emergent behavior

- Systems exhibit characteristics and behaviors not inherent to the components alone
- Systems are sought for these emergent properties
- Projects kick off with user requirements that describe the desired behaviors
- Complex systems are associated with high levels of emergence

Development of Complex Sociotechnical Systems

Sociotechnical systems theory

- “Sociotechnical” is a combination of the words “socio” for people and “technical” for technology
- STS comprise of people applying technology in a social structure toward a goal
- The social and technical elements require one another to fulfil the joint purpose
- Sociotechnical systems theory is aimed at joint optimization of the socio and technical components



Development of Complex Sociotechnical Systems

Cognitive systems are self-organizing.

New technology challenges the existing processes.

Designs for human work should be goal-oriented.

Modelling can support STS development.

STSs are inherently cognitive.

Technology integration problems are expensive to correct.

Piecewise technology introduction project tend to overlook this.

Cognitive Work Analysis

Human systems integration

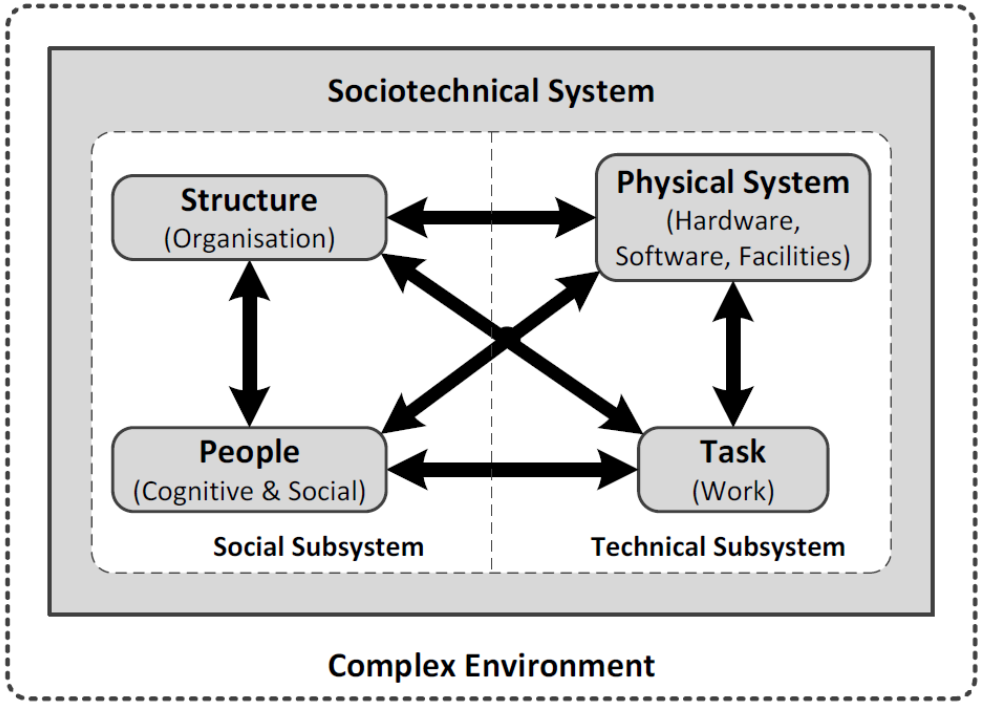
- "…the interdisciplinary technical and management process for integrating human considerations within and across all system elements…"

  (Walden et al. 2015)
- Modern operators experience a counter-intuitive increase in workloads from high technology adaptation
- Safe and reliable operation is contingent on effective HSI
- HSI accounts for as much as 60% of project cost
- Exploring the operation, functional and structural elements of the work domain early may improve safety and efficiency

Cognitive Work Analysis

Design for adaptation

- STSs are open and exposed to unforeseeable events that threaten their effectiveness
- Not all actions operators may need to take can be foreseen
- HSI designs should provide decision support to promote problem-solving

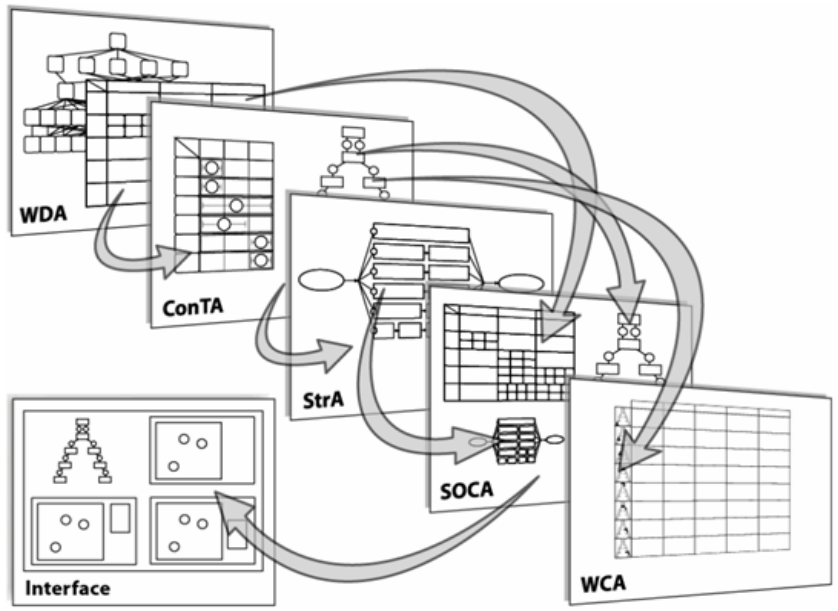


Oosthuizen 2014

Cognitive Work Analysis

Formative framework

- CWA is described as a formative framework
- It focusses on the constraints that affect work demand
- Allows operators to cope with abnormal conditions
- Traditional engineering approaches seek complete design descriptions
- CWA draws on the utility of emergence in cognitive systems



Jenkins et al. 2008

Cognitive Work Analysis

Formative framework

- New technology adjusts the system limits
- The STS responds to re-establish a robust equilibrium resulting in complex emergence
- Emergence resists the reductionist approach of traditional SE
- CWA models help to make the relationships between casual domain functions and objects explicit
- It provides a measure of whether a design will fulfil the intended functional purposes

Cognitive Work Analysis

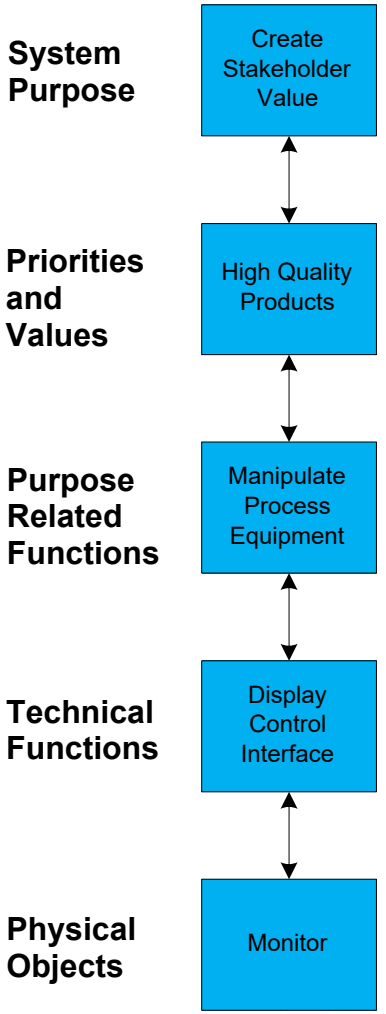
Work Domain Analysis

- WDA provides the foundation for understanding the functional structure of the STS
- It models the work domain and not the system
- A reasoning space about the work environment is produced
- It provides an integrated view of the system purpose and the available resources
- The relationship between the physical resources and the functionality provided needs to be highlighted

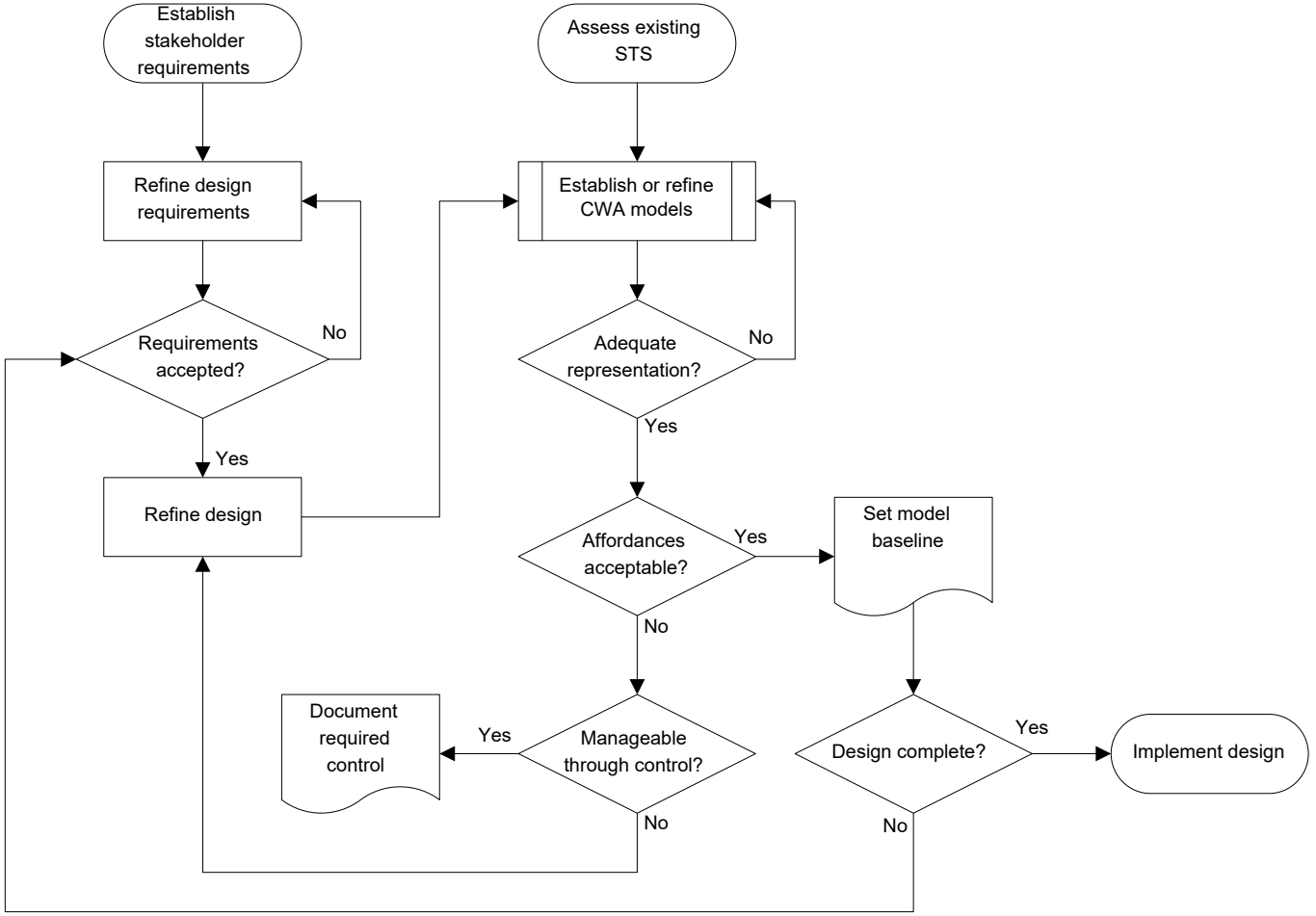
Cognitive Work Analysis

Abstraction Hierarchy

- System purpose represents the ultimate goal of the system
- Priorities and values describe performance metrics
- Purpose related functions identify the knowledge, insight and semantics necessary to satisfy the system purpose
- Technical functions are brought about by the affordances of physical objects
- The work domain comprise physical objects that afford and constrain work



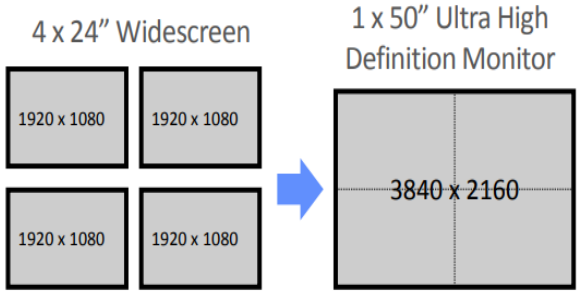
Concept Model



Model Demonstration

Technology change

- Replacement of quad-screen displays with TV monitors
- Replacement of keyboard and mouse interface with a tablet computer



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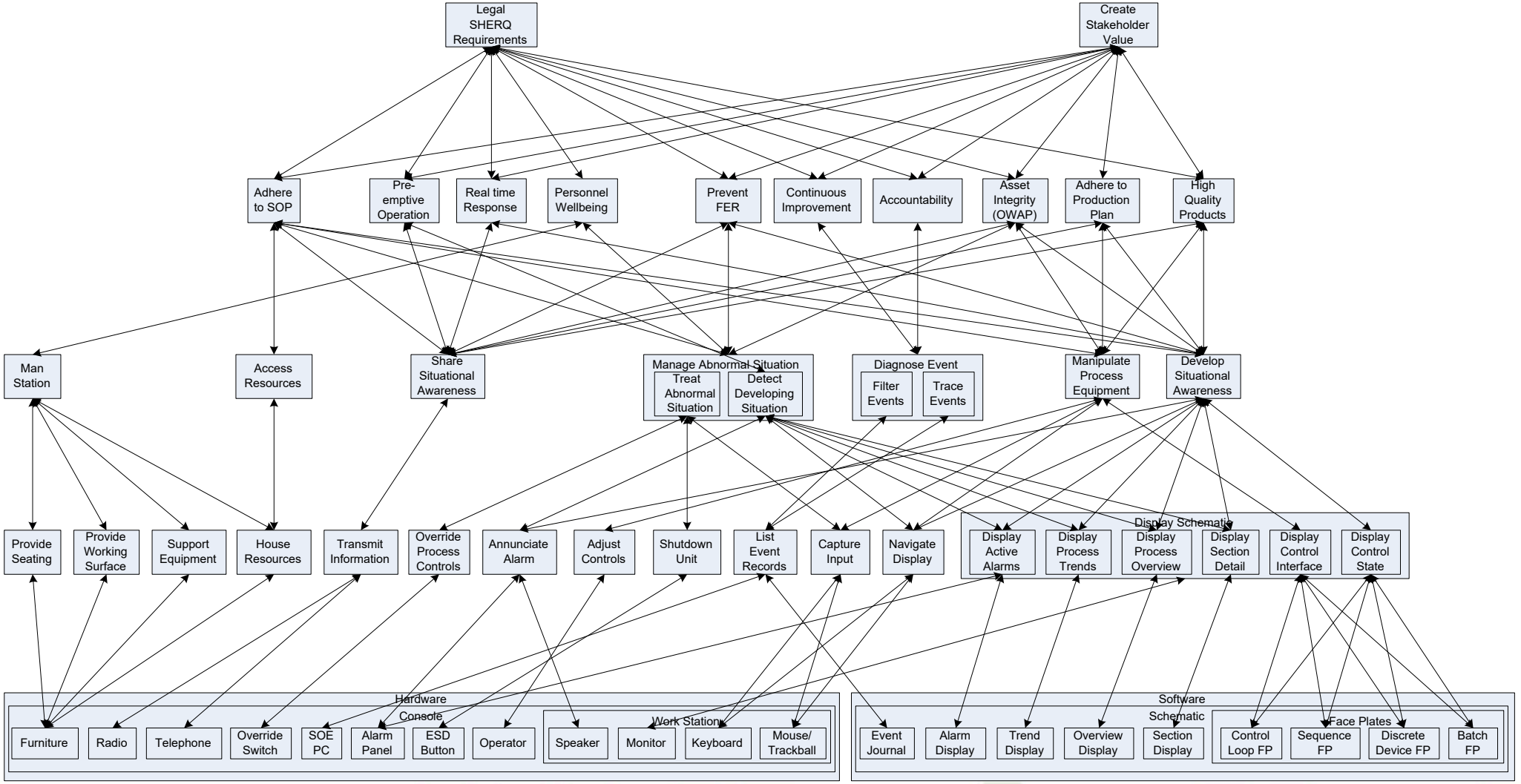

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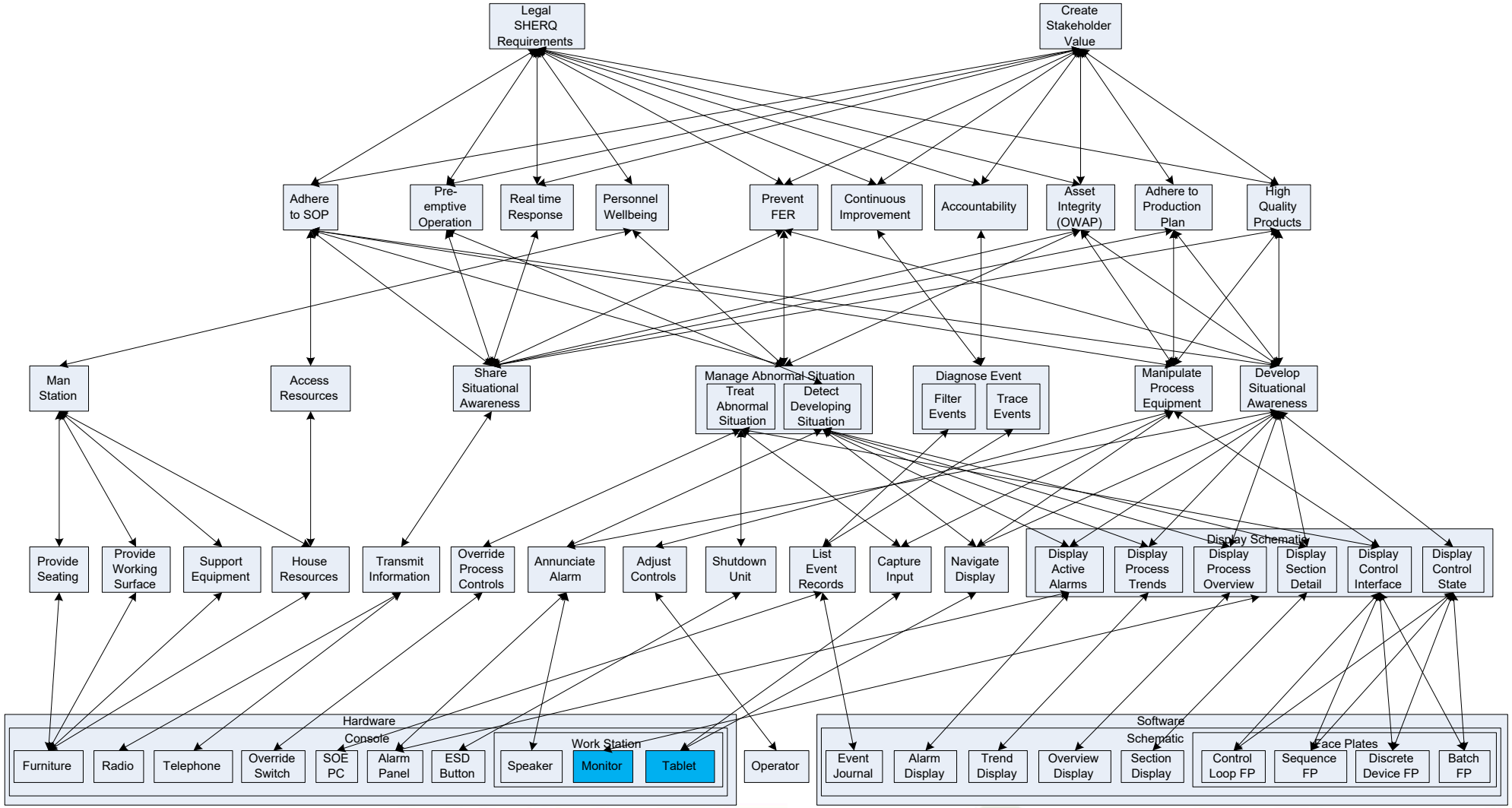
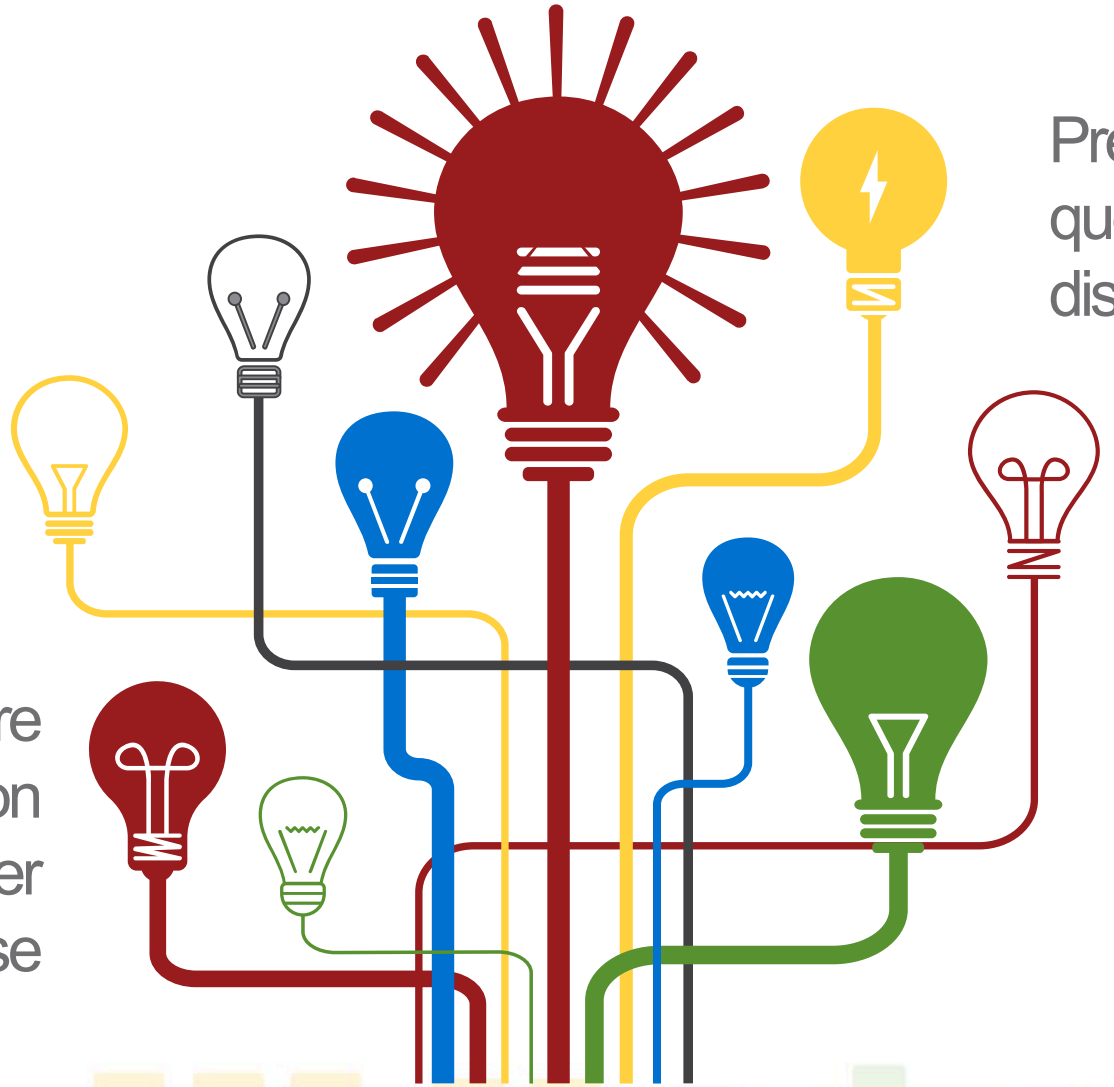


Model Demonstration

Focus group

Is an organized assembly for in-depth or focused interview

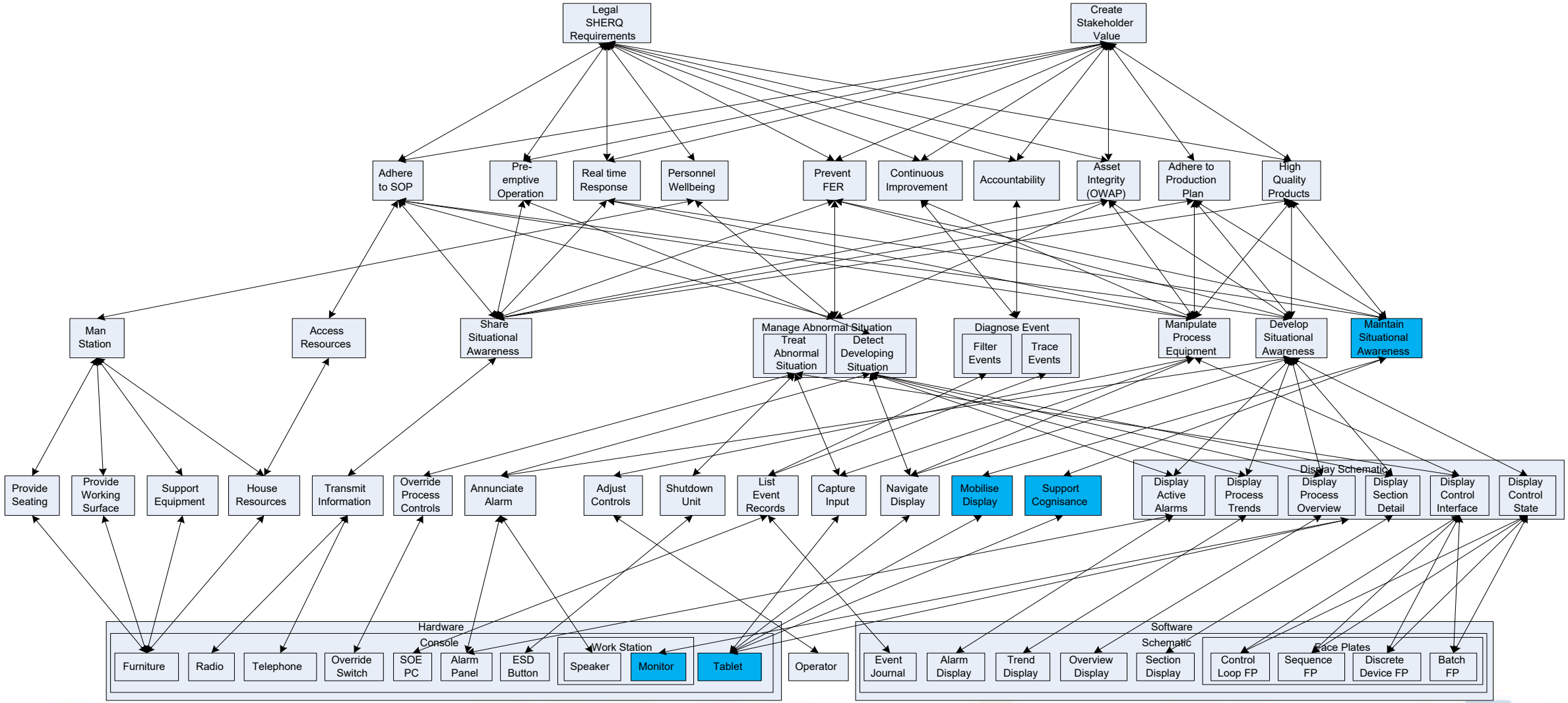
Participants are selected based on subject matter expertise



Predetermined question guide the discussion

Focus groups promotes group interaction

Model Demonstration



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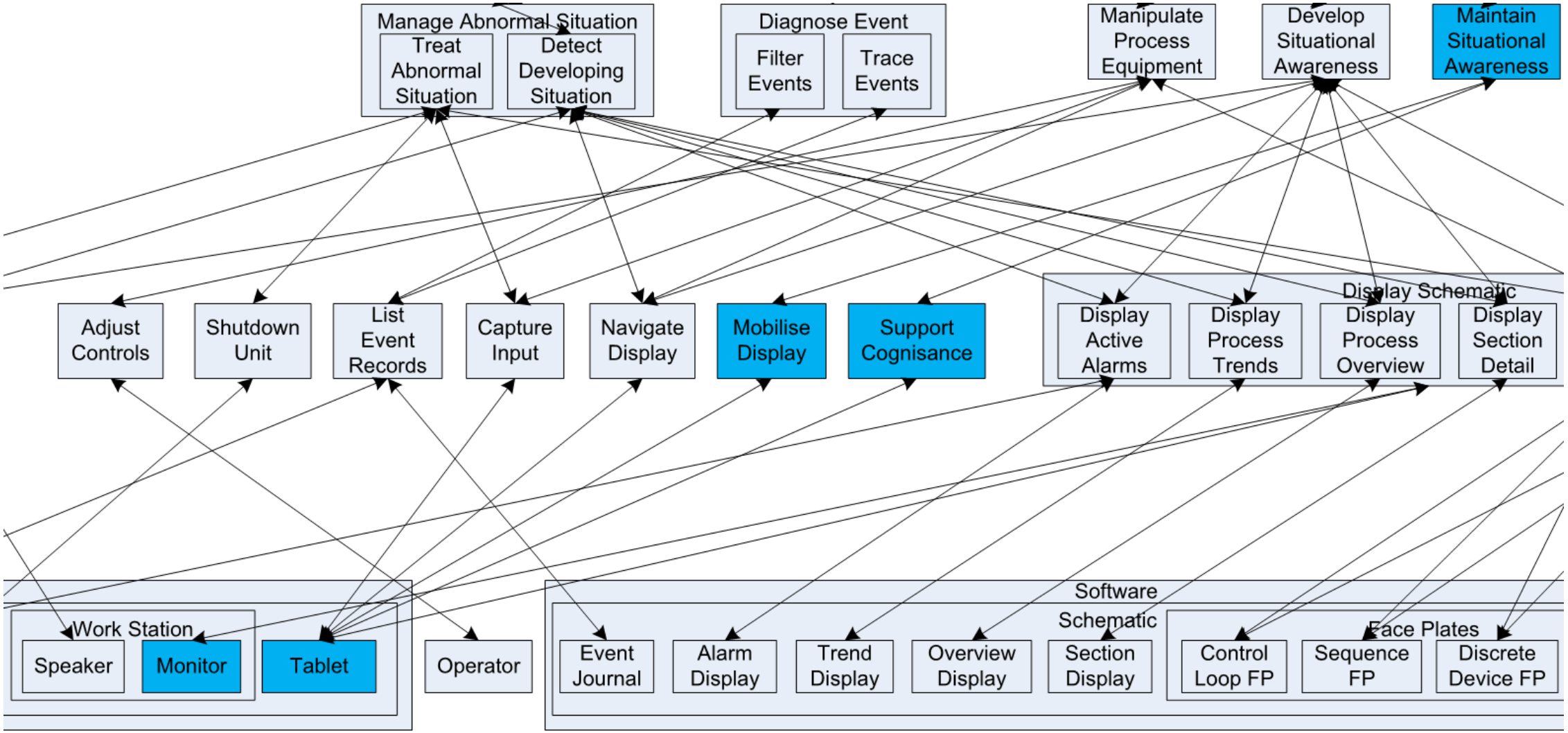
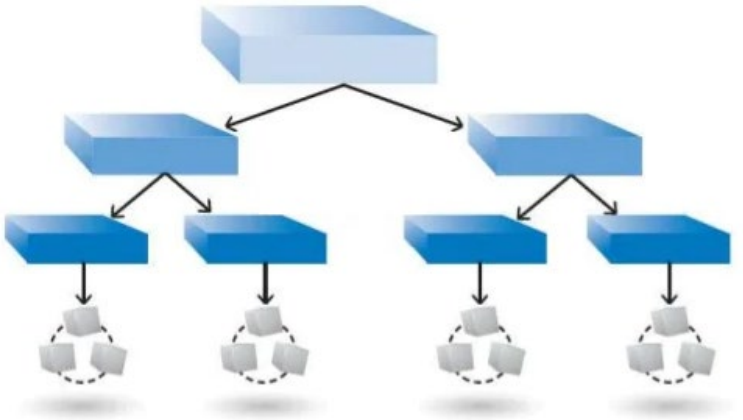


Discussion

- The study was conducted with a group of five engineers with no prior knowledge of CWA of STS concepts
- Individual interviews were used to introduce key concepts
- All interviews were virtual



Discussion

- High familiarity with existing operations may lead experts into contrasting current practices with the analysis process

  Jamieson (2003)
- Most of the benefit of WDA lies in participation
- Participants may not be forthcoming due to fear of providing “socially” unacceptable answers

  Barry et al. (2008)
- Morale and participation is enhanced through inclusion

Discussion

- Application of the proposed methodology resulted in the uncovering of previously unforeseen affordance
- The outputs can be applied to inform user requirements
- Additional applications in support of the SE life-cycle were identified
  - To test technical viability in pre-feasibility
  - To validate functionality during construction and implementation
  - To act as baseline for planning of future changes

Conclusion and Future Research

- WDA is useful as part of requirements analysis
- It is helpful at combining different perceptions
- Even with limited experience the method can bare fruits
- Future research should assess application beyond the early phase of SE
- Future research should assess the benefit of other CWA methods

Questions?

Thank you

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