Human Factors of Transmission Operations

Summary Principles from a Collaborative Research Project

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NERC Human Performance Conference

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Cognitive Engineering Laboratory

Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

Research at CEL

COGNITIVE ENGINEERING LABORATORY

Conviction: Skilled, knowledgeable operators are an **invaluable** and **irreplaceable** asset in safety-critical systems

- Applied Psychology
  - control interfaces
  - automation behaviour
- Systems Engineering
  - Overall Performance, Efficacy, Resilience
  - Make Workers Smarter
  - & Operations Safer

Study: Transmission Grid Operations

- Collaboration with IESO
- Questions:
  1. Near-term opportunities?
  2. Future control room requirements?
  3. Guiding principles?

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HF Principles we concluded:

1. Put data in context when context can be pre-determined
2. Design databases to be summarized
3. Support parallel visual processing
4. Mitigate risks to signal-to-noise ratio
5. Support fast-expert action with consistent formatting and navigation
6. Develop expertise when workload is low, support it when busy
7. Automate the consistency maintenance of knowledge bases
8. Clearly distinguish between boundaries of automation responsibility
9. Capture operation requirements early in tool procurement or design

Parallels with Endsley's (2012) Situation Awareness principles

1. Put data in context when context can be pre-determined

"#1: Organize information around goals"

3. Support parallel visual processing

"#7: Take advantage of parallel processing capabilities"

5. Support fast-expert action with consistent formatting and navigation

"#49: Have standardized display coding"

7. Automate the consistency maintenance of knowledge bases

"#45: Information sources should be consistent"

Example Method for Principles

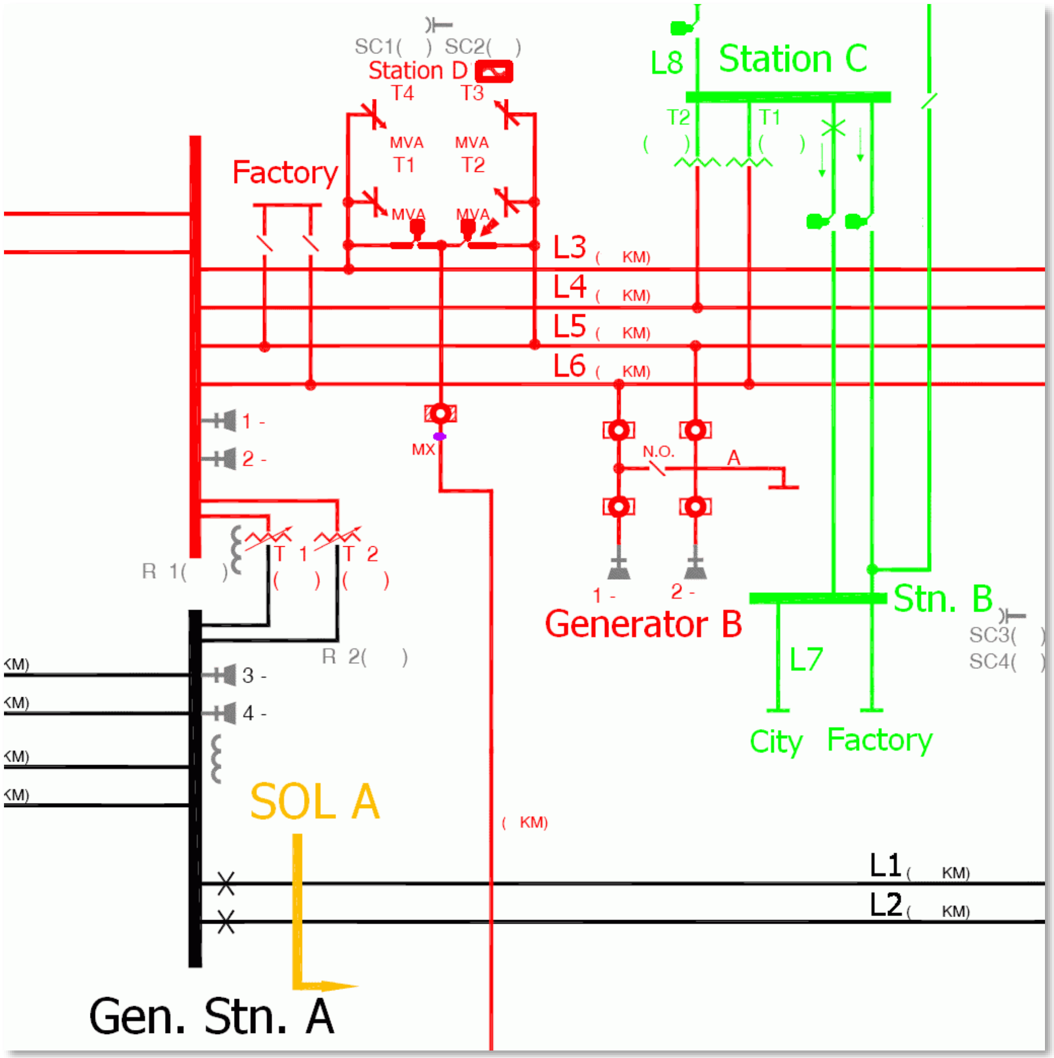
1. Put data in Context
2. Design Databases to be Summarized

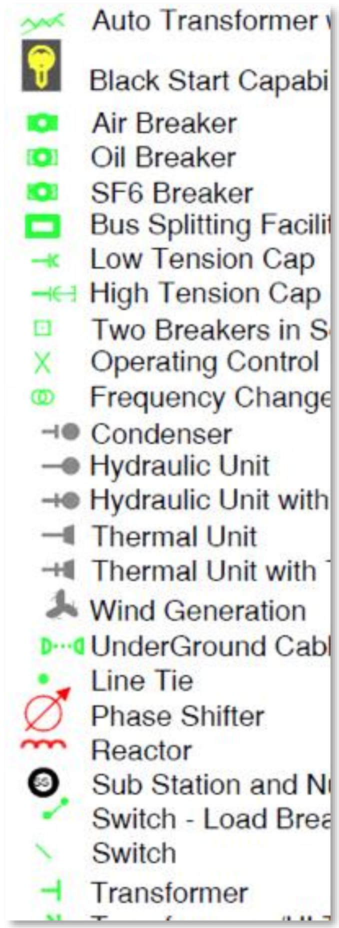
Human Factors of Grid Databases

- How to structure information for reliable human performance? Must:
  - Match mental model**(s)** of operators, engineers
  - Be correct, valid even for unrecognized situations
  - Be consistent within and across tools
- Method: Work Domain Analysis
  (Rasmussen 1986, Naikar 2013)
  - Functional modeling of system constraints
  - Psychologically relevant

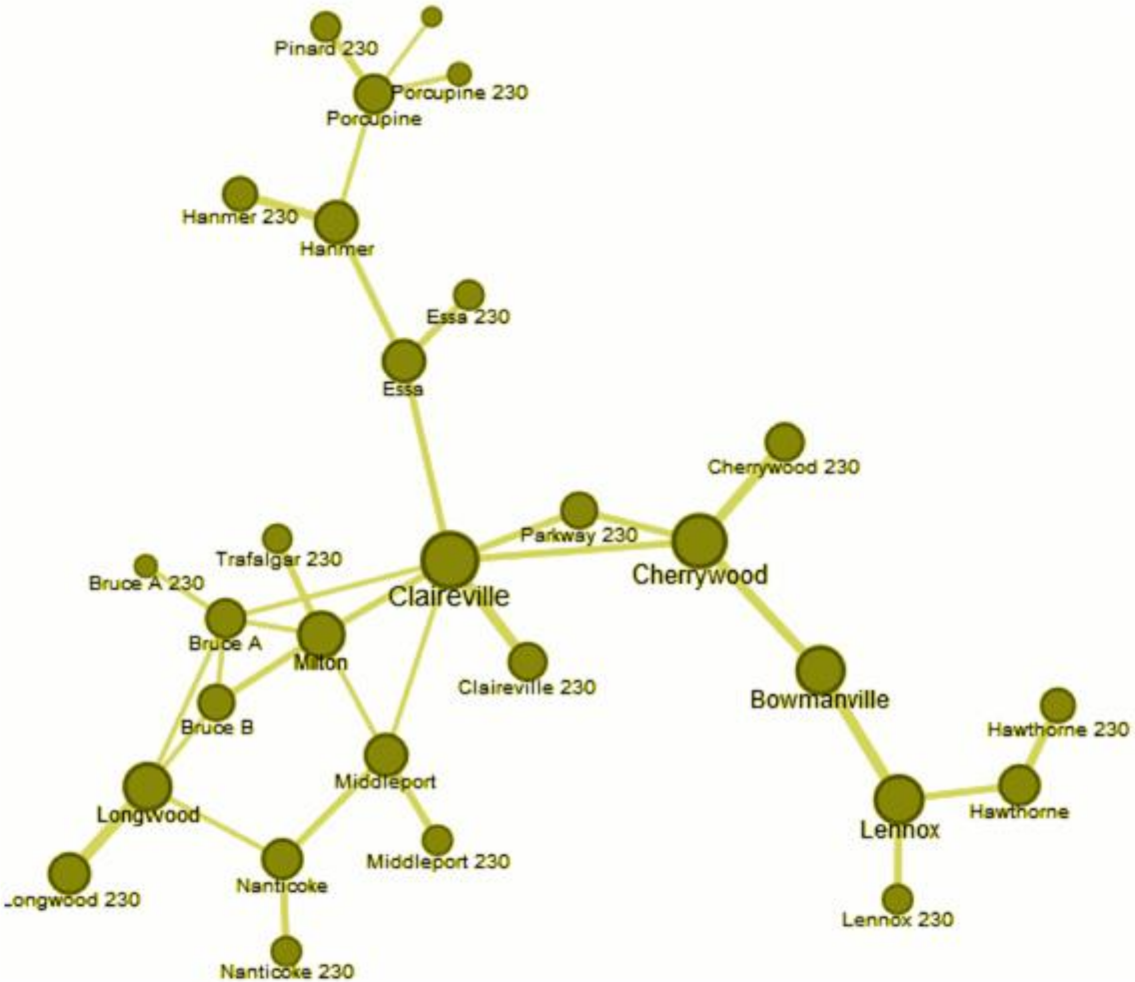
Work Domain Analysis Applications

- Military (Australian Air Force)
  - AEW&C procurement & training support (Naikar & Sanderson 2001)
  - Revising Air Power Doctrine and Strategy (Treadwell & Naikar 2014)
- Aviation (TU Delft)
  - Centralized Air Traffic Control
  - Decentralized Collision Avoidance (Borst, 2016)
- Power Generation (INL, UQ)
  - Future Fast Sodium Reactor Operational Concept, Idaho National Lab (Hugo & Oxstrand 2015)
  - Hydropower Market Strategies Snowy Hydro, Australia (Memisevic et al. 2007)





Reliability Coordinators already do functional modelling



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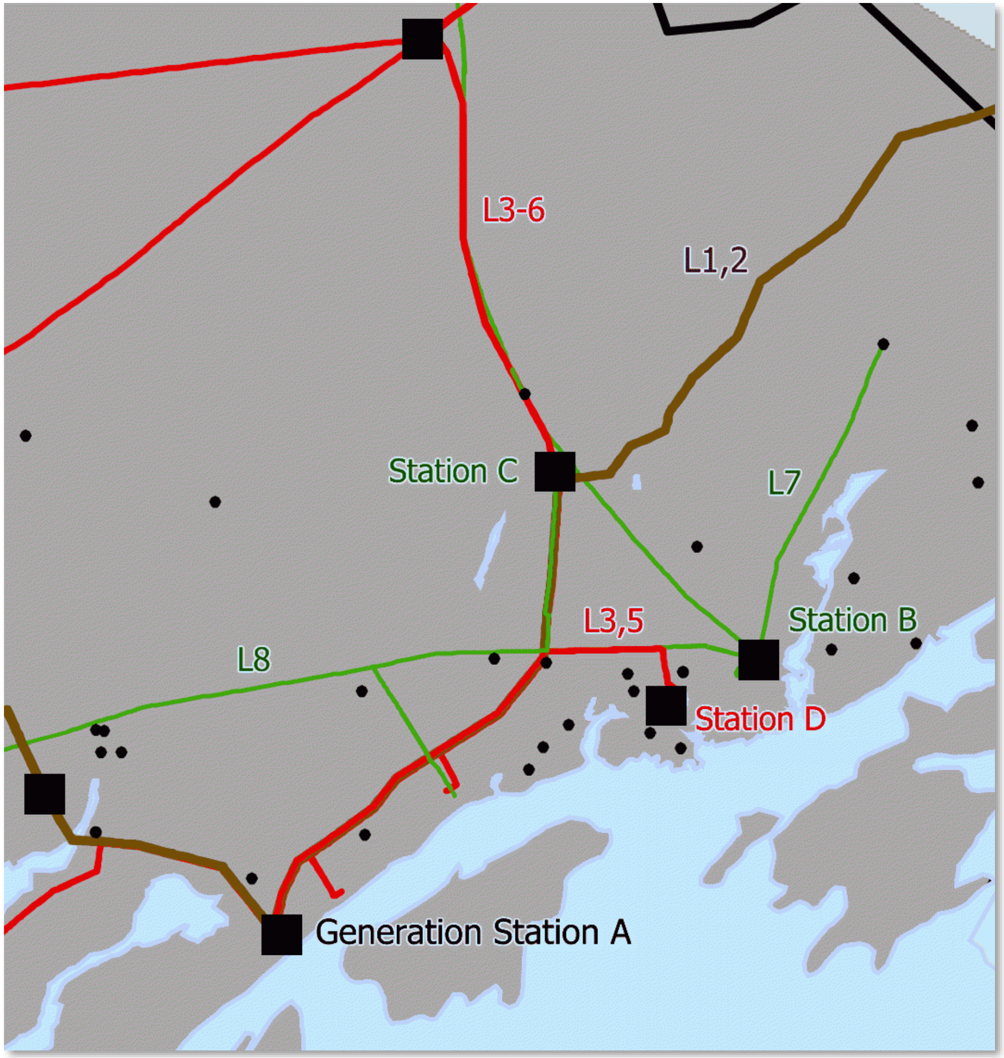
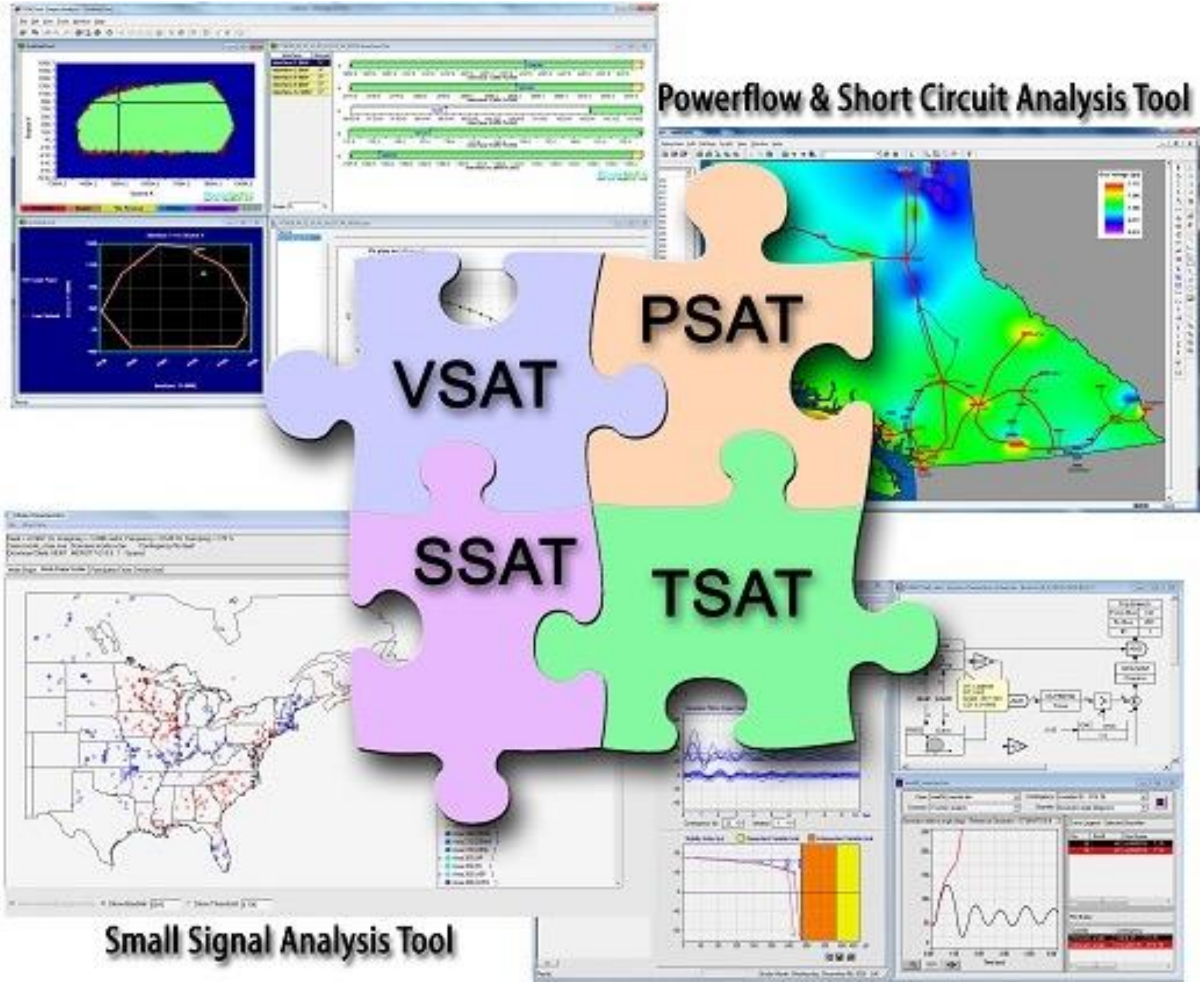


Less-integrated levels of abstraction

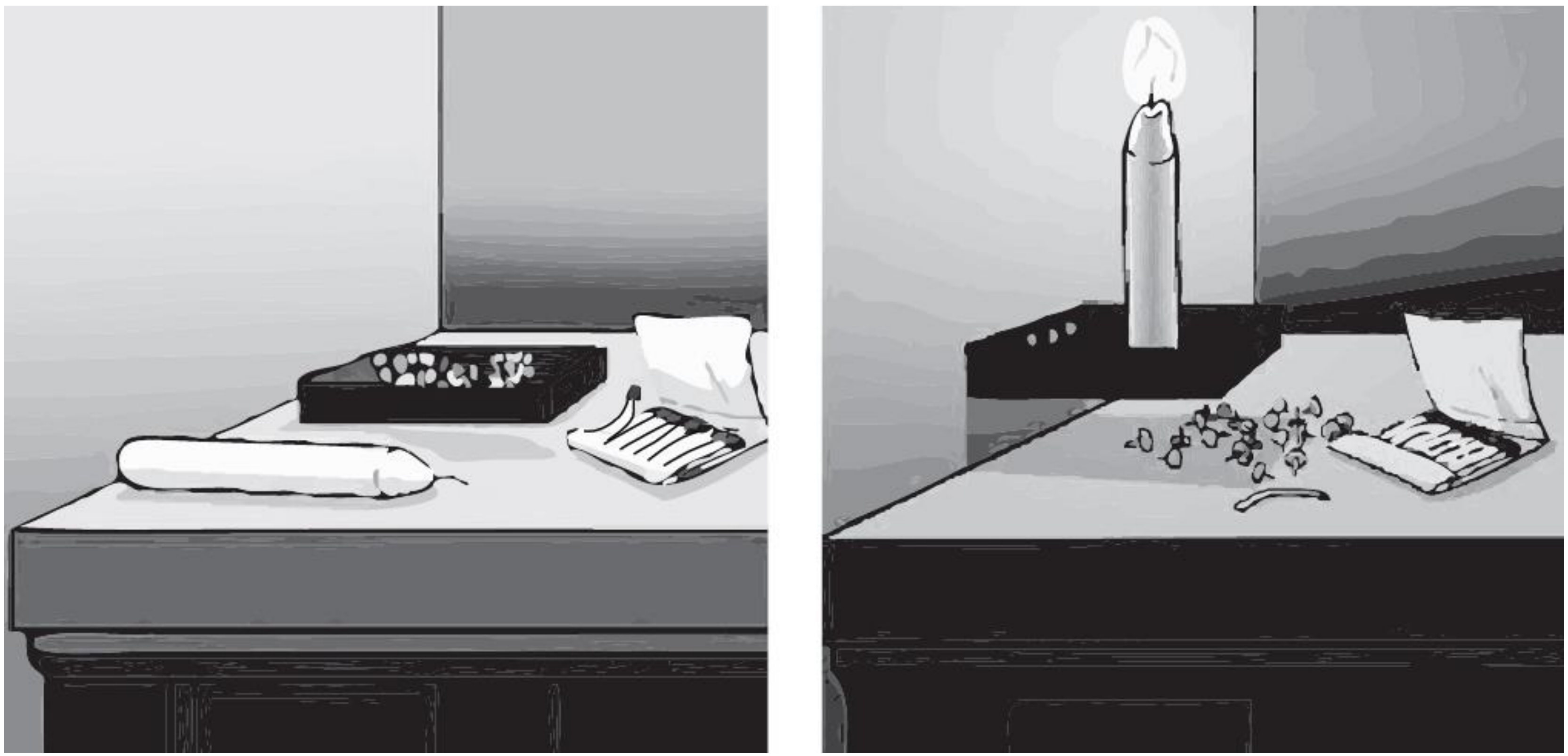


Less-integrated levels of abstraction

Context from Means-Ends relations

Context from Means-Ends relations

(Duncker, 1945)



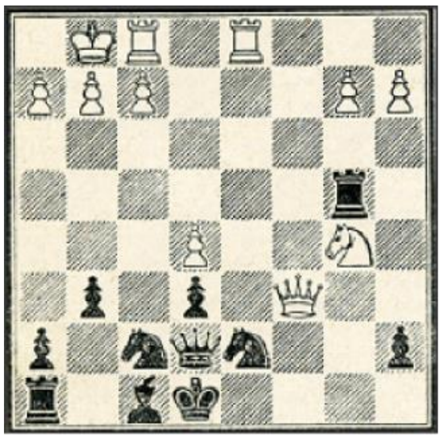
Context from Means-Ends relations

Priorities, Risk tolerance?
Consequences of Faults?

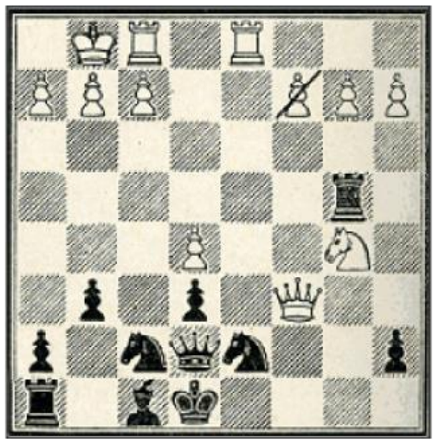
Capabilities Available? Source of Faults?

Summary Overview by Part-Whole

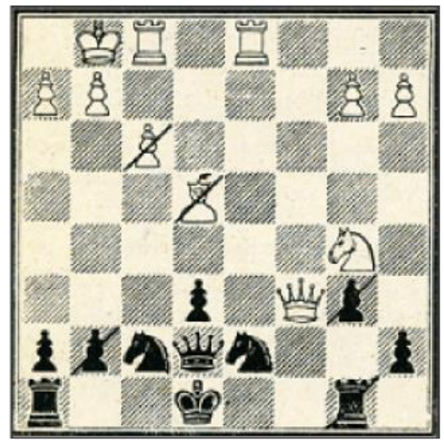
(DeGroot 1946)



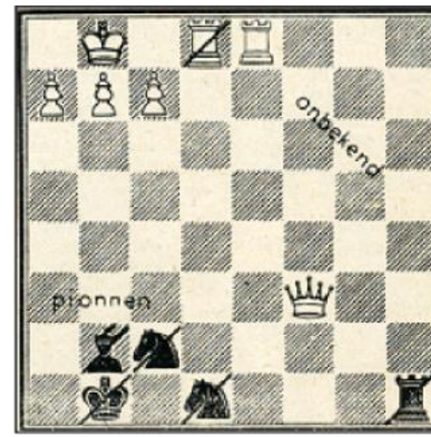
Grand master
22 pt (100%)



Master
21 pt (95%)



Expert
17 ptn (73%)



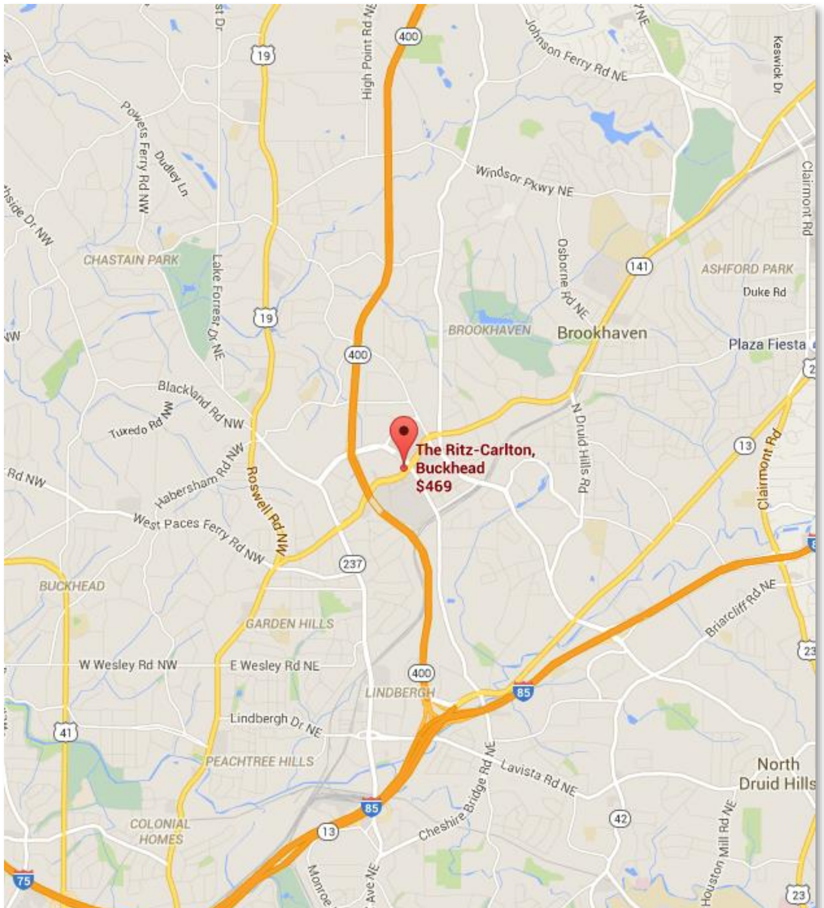
Class player
9 ptn (41%)

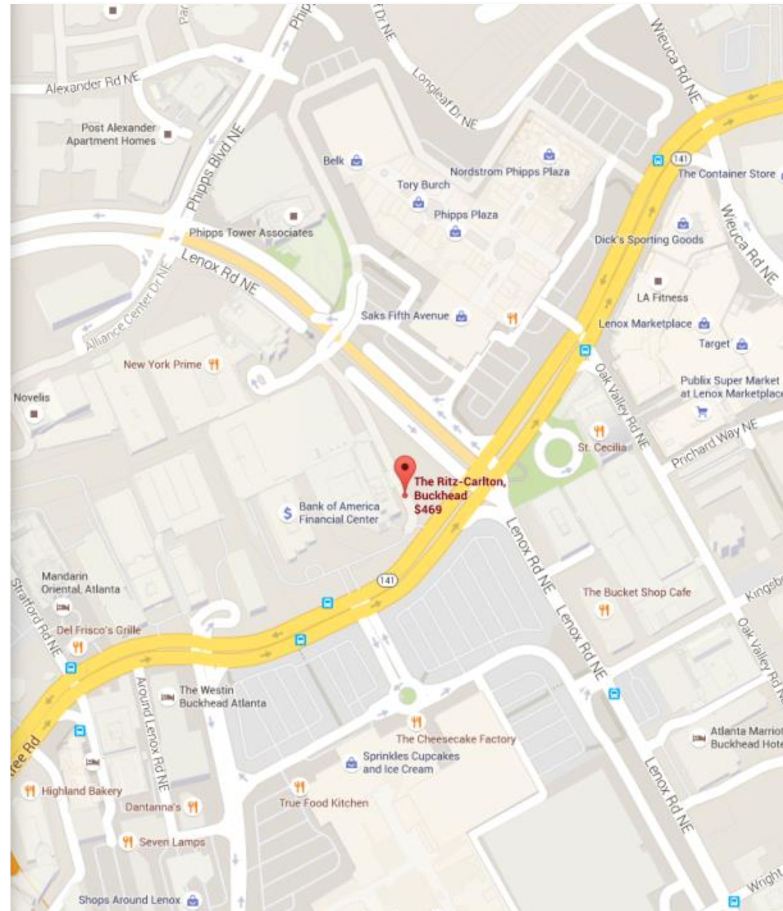
- Working memory may be 7 +-2 … what?
- Experts group by functional “chunks” (Chase & Simon 1973)

Summary Overview by Part-Whole

Purposes of Grid	⇨	Balancing different NERC regulations?
Stability, Performance	⇨	"Pockets", "exposed", risky, stressed areas?
Power Flows	⇨	Real, Reactive components Area Control Error → Monitoring Areas? → System Operating Limits → Line flows
Equipment Functions	⇨	Interties between zones → Grouped lines? → Individual transmission lines → Distribution network. Generation stations → Generator units.
Physical Equipment	⇨	Substations → Housed Equipment Parts of weather systems (relative to equipment)

Grid Monitoring Applications?

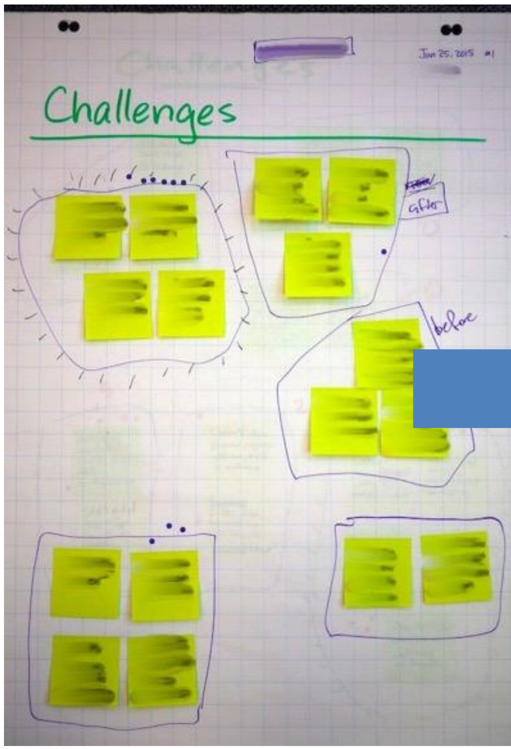




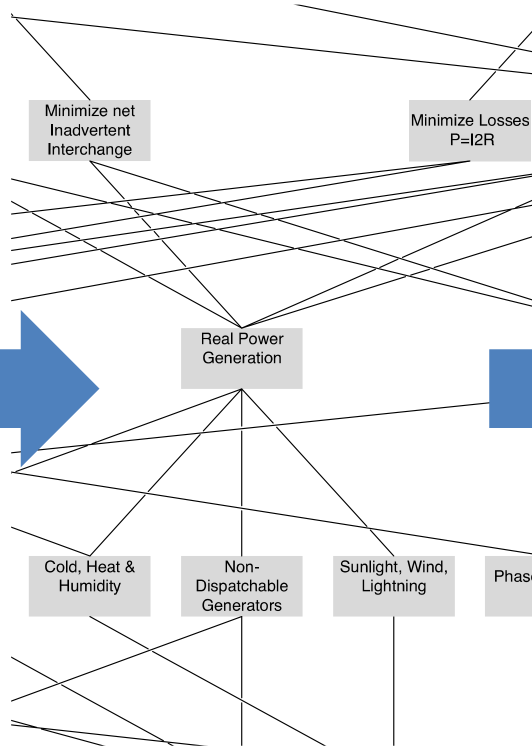
Example Process for Principles

9. Capture operation requirements early in tool procurement or design

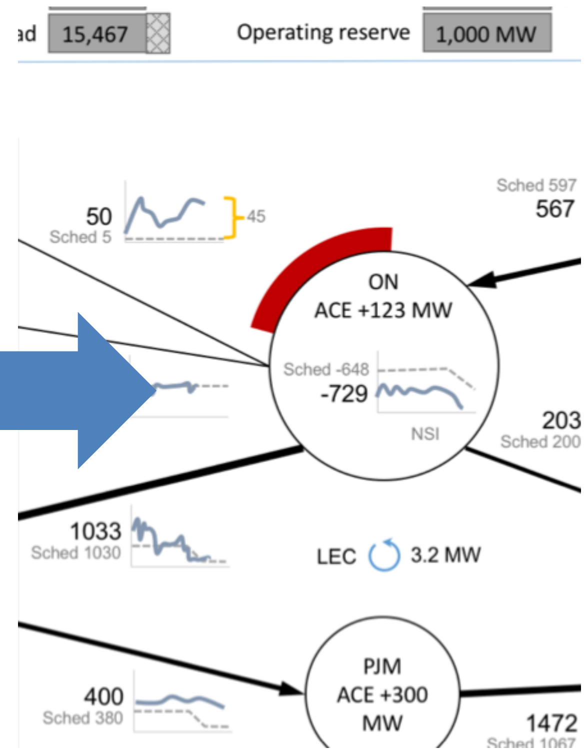
Involve operators throughout design process



Interviews, focus groups

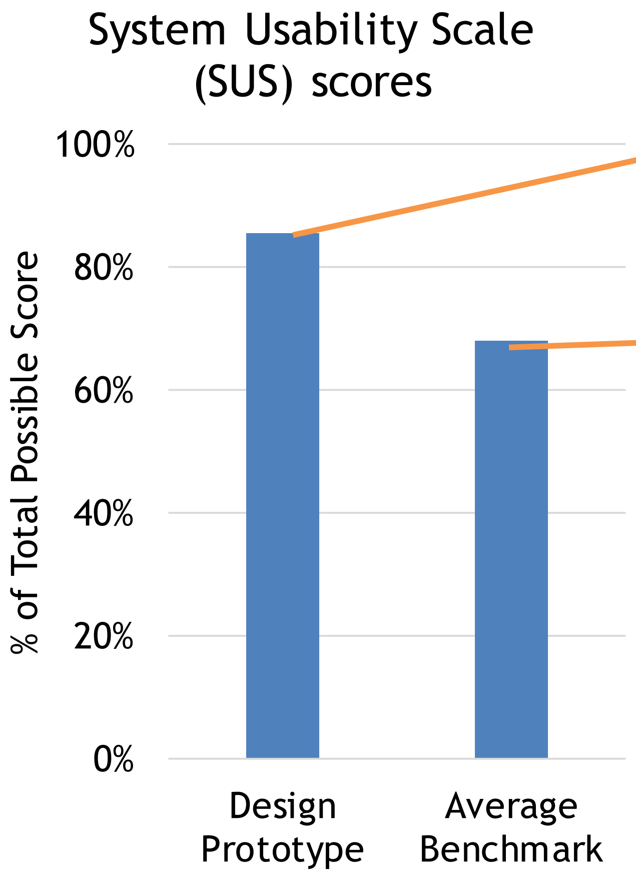


Work Domain Analysis



Design and usability testing

Prototype Design Evaluation



Design Prototype: 85%

Average benchmark: 68%
(Sauro, 2011)

Recommendations

1. Our 9 principles can guide human performance improvements
2. Work Domain Analysis is a method for improving information system design
3. Involving end users is imperative in work tool design or procurement

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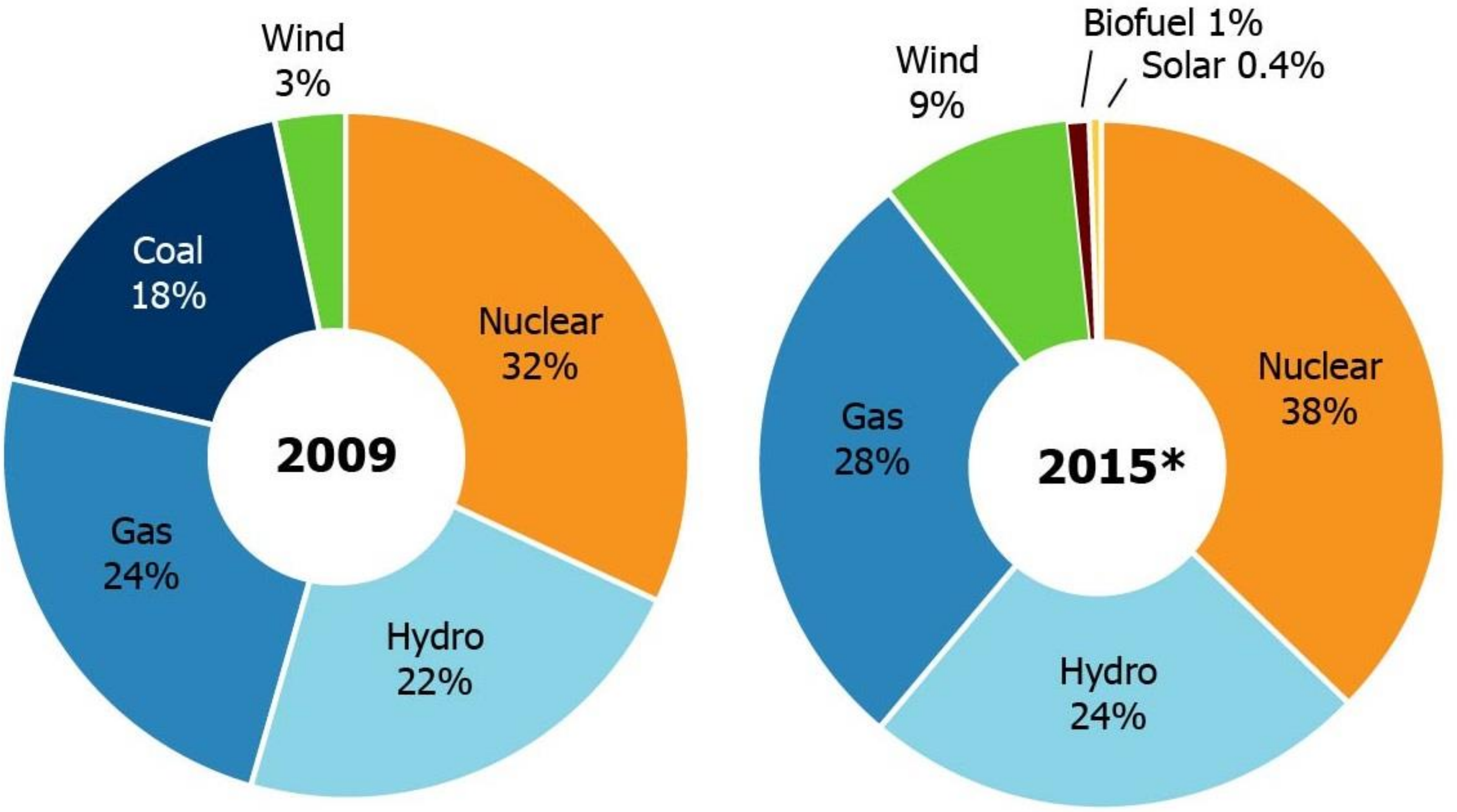
Ontario's Supply Mix: Changing!



*2015 Figures as of September 2015.
Due to rounding, numbers may not add up to 100.

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Change?

Thank you.

Questions, comments?

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References

Borst, C. (2015). Delft Ecological Design [Research Group Summary]. Retrieved March 18, 2016, from http://www.delftecologicaldesign.nl/

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*(1), 55–81. http://doi.org/10.1016/0010-0285(73)90004-2

Groot, A. D. de. (1946). *Thought and choice in chess*. The Hague: Mouton.

Hilliard, A., Tran, F. F., & Jamieson, G. A. (in press). Work Domain Analysis of Power Grid Operations. In N. A. Stanton (Ed.), *Cognitive Work Analysis: Applications, extensions, and the future*.

Hugo, J., & Oxstrand, J. (2015). *Example Work Domain Analysis for a Reference Sodium Fast Reactor* (No. INL/EXT-15-34036) (p. 80). Idaho Falls, ID: Idaho National Laboratory Human Factors, Controls and Statistics Department. Retrieved from http://dx.doi.org/10.13140/RG.2.1.2845.4482

Memisevic, R., Sanderson, P. M., Wong, W. B. L., Choudhury, S., & Li, X. (2007). Investigating human-system interaction with an integrated hydropower and market system simulator. *IEEE Transactions on Power Systems*, *22*(2), 762–769.

Naikar, N., & Sanderson, P. M. (2001). Evaluating design proposals for complex systems with work domain analysis. *Human Factors*, *43*(4), 529-542.

Naikar, N. (2013). *Work domain analysis: concepts, guidelines, and cases*. Boca Raton: CRC Press.

Rasmussen, J., Pejtersen, A. M., & Goodstein, L. P. (1994). *Cognitive systems engineering*. New York: Wiley.

Sauro, J. (2011). *A practical guide to the System Usability Scale: Background, benchmarks, & best practices*. Denver, CO: Measuring Usability LLC.

Treadwell, A., & Naikar, N. (2014). *The Application of Work Domain Analysis to Defining Australia's Air Combat Capability* (No. DSTO-TR-2958). Defence Science and Technology Organisation (Australia). Air Operations Division. Retrieved from http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA611427