Cognitive Systems Engineering Workshop

Cindy Dominguez
Klein Associates Division of ARA
14 Blackford Drive
Exeter, NH 03833 U.S.A.
cdominguez@ara.com

Corey Fallon
Klein Associates Division of ARA
1750 Commerce Center Bv North
Fairborn, OH 45324 U.S.A.
cfallon@ara.com

Gary Klein
Klein Associates Division of ARA
1750 Commerce Center Bv North
Fairborn, OH 45324 U.S.A.
Gary@decisionmaking.com

Laura Militello
University of Dayton Research Institute
300 College Park
Dayton, OH 45469 U.S.A.
Laura.Militello@udri.udayton.edu

Gavan Lintern
Cognitive Systems Design
Melbourne
Australia
glintern@cognitivesystemsdesign.net

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Workshop Objectives

- Hands-on how-to learning.
- Ability to undertake the rudiments of CSE.
- Description/demonstration of the concept of macrocognition.
- Demonstration of a small set of CSE methods.
  - Cognitive Indicators of system effectiveness.
  - Critical Decision Method for Cognitive Task Analysis.
  - Decision Requirements analysis.
- Expansion of perception/conception of cognitive requirements.
  - Stronger ability to “see” cognition.

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CSE Workshop Agenda

0900- 0930	Workshop introduction
0930- 1030	Information Management Exercise
1030- 1045	Break
1045- 1130	Critical Decision Method: Overview and Demonstration
1130- 1200	Debrief IMX Observers
1200- 1330	Lunch
1330- 1345	Introduction to Macrocognition
1345- 1420	Build a Decision Requirements Table
1420- 1500	Group Exercise: Design Concept Development Part 1
1500- 1515	Break
1515- 1525	Group Exercise: Design Concept Development Part 2
1525- 1550	Cognitive Performance Indicators
1550- 1615	Redesign the Data Collection
1615- 1630	CSE Bibliography; Wrap up

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What is Cognitive Systems Engineering?

- A design approach aimed at improving the cognitive requirements of work.
  - Links system features to the cognitive processes they need to support.
  - Primarily applied to design of information technologies to make them easier to use and more likely to be adopted.

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Major CSE Frameworks

- Cognitive Work Analysis
- Decision-Centered Design
- Situation Awareness-Oriented Design
- Work-Centered Design
- Applied Cognitive Work Analysis

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Cognitive Work Analysis

Vicente, 1999

- Formative Approach
- Constraint-Based
- Representation/Modeling tools

	Total system	Sub-system	Function unit	Sub-assembly	Component
Functional Purpose			WHY?		
Abstract Function	WHY?		WHAT?		
Generalize Function	WHAT?	WHY?	HOW?		
Physical Function	HOW?	WHAT?			
Physical Form		HOW?			

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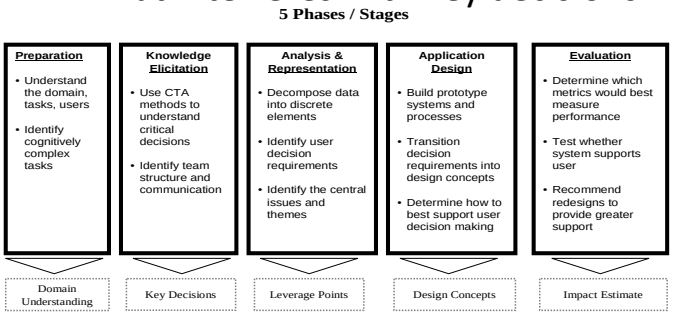
Figure adapted from Vicente, K. (1999) *Cognitive Work Analysis.* Mahwah: Erlbaum, p. 166.

Decision-Centered Design

Hutton et al, 2003

- Focus on key decisions
- What makes decision difficult
- What interferes with key decisions



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Situation Awareness-Oriented Design

Endsley, Bolté, & Jones, 2004

Three stage process

- SA Requirements Analysis
- SA-Oriented Design Principles
- SA Measurement

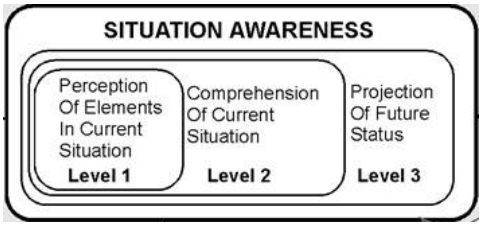


Figure adapted from Endsley, M.R. & Garland, D.J. (2000) *Situation Awareness Analysis and Measurement.* Mahwah: Erlbaum, p.6.

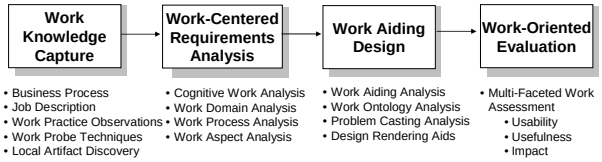
Work-Centered Design

Eggleston, 2003

Guided by three principles

- Problem-Vantage-Frame Principle
- Focus-Periphery Organization Principle
- First-Person Perspective Principle

Work-Centered Design (WCD) Framework



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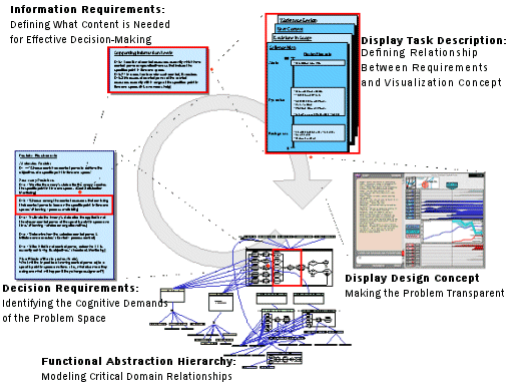
Applied Cognitive Work Analysis

Potter, Elm, Roth, Gualteiri, & Easter, 2002

- Adapted from Cognitive Work Analysis
- Intermediate design artifacts
- Functional Abstraction Network



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Charter for the Day

Mission Statement:
Supporting Small Team Decision Making in a Command & Control Task

You have been commissioned to undertake a CSE project involving the research and design of technology and training concepts that support team decision making and other cognitive work in a command and control environment.

An aerospace engineering company (who wishes to remain anonymous) has failed miserably in its first attempt to do so, and has engaged HFES to conduct a workshop in October, 2009 to gain fresh insights and recommendations to support this problem space.

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Consulting Service Agreement with CognoSpaces Inc. (not the real name)

Project Goals:

Identify the cognitive requirements for small teams working together, networked to a larger operational and planning community.

Consider the range of cognitive activities involved in this domain, including:

- Sensemaking, team and individual
- Decision making
- Attention management
- Problem detection

Under conditions of Time Pressure, Uncertainty, Vague Goals, and High Stakes.

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Consulting Service Agreement continued

Project Plan:

Identify cognitive requirements.

Recommend concepts for meeting those requirements. These should focus on information technology but can include other types of technologies.

Approach:

Learn about and practice observation, interviewing, representation/analysis, and concept development

Deadline:

COB October 19, 2009.

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Interviewing: Critical Decision Method

Incident-Based Methods

Interview is grounded in a real, lived incident.

- Increases accuracy of recall
- Facilitates discussion of context
- Encourages first-person perspective
- Evokes detailed memories

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Cognition in context

Get inside the heads of experts and look at the world through their eyes

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Knowledge Elicitation

- How do you get people to tell you what is going on inside their heads?
  - at some point, have to ask…

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Typical Questions

- How do you do your job?
- What do you think about when you do X?
- What is the most important part of your work?

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Typical Answers

- “It depends…”
- Generic/textbook answers
- Observations indicate these responses don’t tell us how people actually DO the task
- Issue is: how to get good accuracy and high information value?

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Examples of Incident-Based Methods

- Critical Decision Method
  - Hoffman, Crandall, Shadbolt, 1998
- Cued-Retrospective Interviews
  - Omodei, Wearing, & McLennan, 1997
- Applied Cognitive Task Analysis (ACTA)
  - Militello & Hutton, 1998
- Team CTA
  - Klinger, Phillips, Thordsen, 2001

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Critical Decision Method Background

- Based on Flanagan's Critical Incident Technique (1954)
- Structured around real, lived experiences
- Goal is to uncover critical cognitive elements and surrounding context
- Flexible; can be adapted to a variety of purposes

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The CDM "Sweeps" Overview

1. Incident identification and selection
2. Timeline verification and decision point identification
3. Deepening; the story behind the story
4. "What if" queries, expert-novice differences, decision errors, etc.

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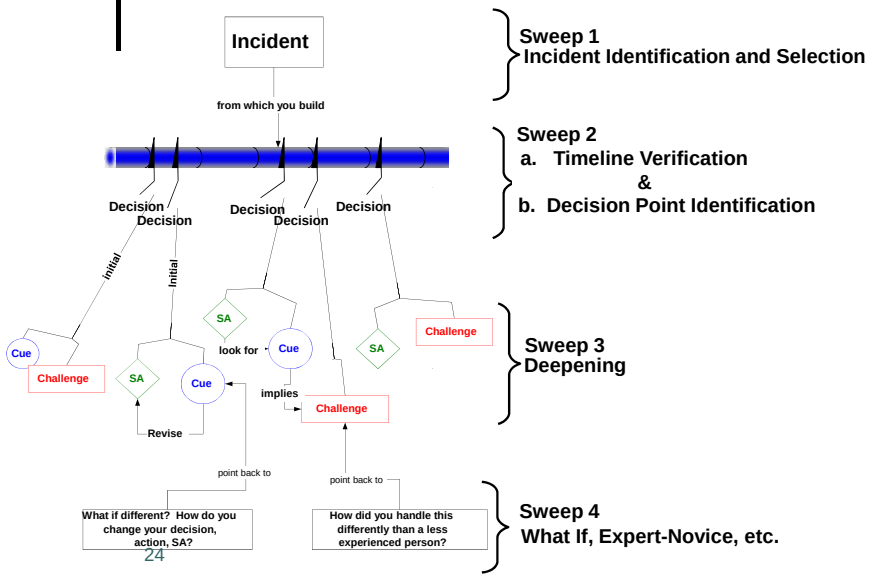
The CDM "Sweeps"



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CDM

- Demanding, requires considerable skill to do well
- Provides rich, specific, detailed data and lots of it
- Supports wide variety of analyses and representation formats

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Introduction to Macrocognition

Cognitive Systems Engineering

- Goal: Support cognitive functions.
- But:
  - What are these functions?
  - How are they accomplished?
  - How should they be supported?
- If we are going to design IT to support cognitive functions, we need to be clear about what those functions are
- Otherwise we run the risk of designing the wrong systems right
- Macrocognition is a framework for carrying out cognitive systems engineering

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Macrocognition

- Macrocognition (the cognitive dimension) is the study of cognitive adaptations to complexity
- This cognitive dimension consists of several functions and processes

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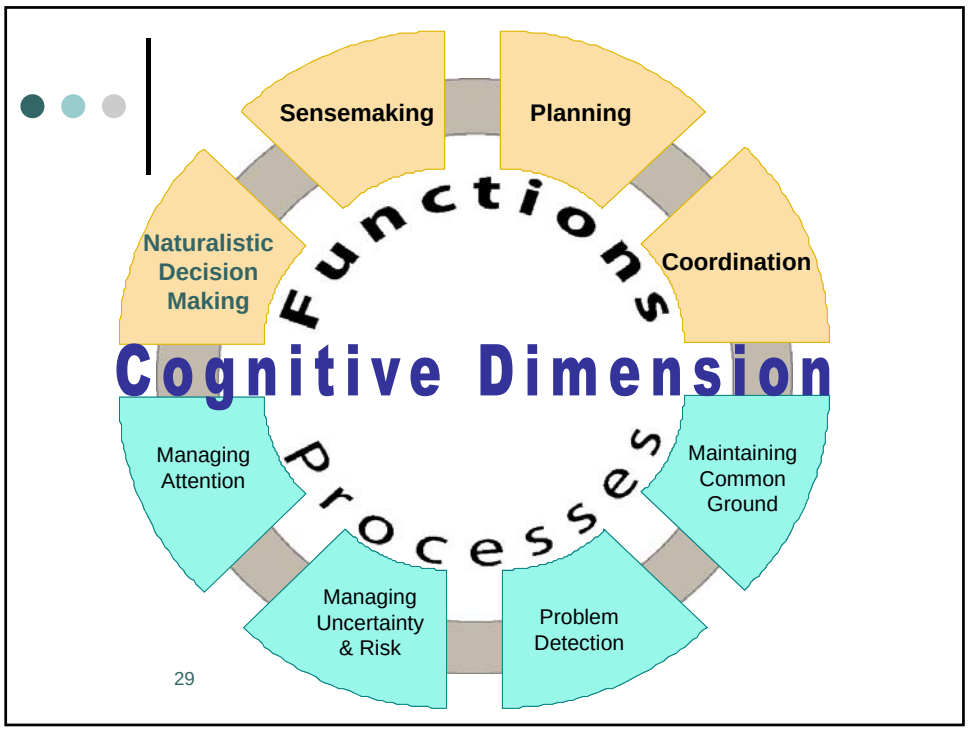

The functions and processes of Macrocognition contrast with Microcognition

Microcognition	Macrocognition
Puzzle Solving	Planning and replanning
Searching a problem space	Problem detection
Selective attention	Building courses of action from leverage points
Choosing between options	Attention management
Estimating uncertainty values	Recognizing situations
	Managing uncertainty

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Decision Requirements Table

Decision Requirements Tables

- Representation technique to aid in analyzing qualitative data
- Used to organize and highlight key decisions
- Should help the researcher explore answers to the following questions
  - What makes the decision difficult?
  - What critical cues are relevant?
  - What are some potential errors that novices would make when faced with this decision or assessment?
  - What design ideas or solutions might be considered?

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Decision Requirements Table

Decision/ Assessment	Why Difficult?	Critical Cues/ Anchors	Potential Errors	Design Ideas

How do you fill the table?

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Coded Interview Notes Example

Interview Notes

At that point I jumped on the scope. I knew this is no longer a time to stand back and observe. I looked on the scope to get an idea of the contact's range and bearing. Based on what I saw I knew we did not have a lot of time to analyze the situation. Less experienced guys might not recognize that they don't have a lot of time to make a decision. I knew We had to maneuver immediately.

Coding

- Interviewee assessed that he needed to intervene
- Interviewee identifies several cues he must consider when assessing the situation
- The decision is challenging due to time pressure
- Novice error –to recognize how much time is available to make a decision

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Coded Notes to DRT

- DRTs are an intermediate analysis tool to help researchers structure their analysis

Decision /Assessment	Why Difficult?	Critical Cues / Anchors	Potential Errors	Design Ideas
Must decide whether or not to maneuver ownship in response to a contact of concern	The Commanding Officer has very little time to make this decision.	The contact's range and bearing	Failing to recognizing that the decision must be made immediately.	System that tracks time available before maneuver must be made based on ownship and contact parameters

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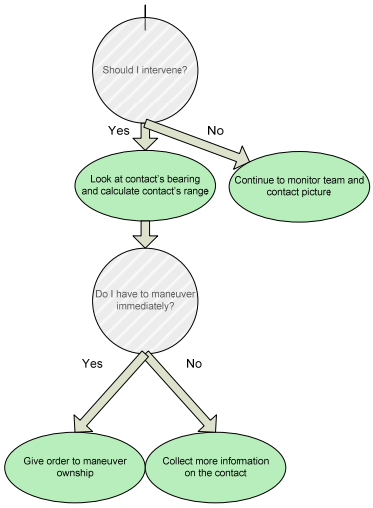
DRTs can be used to help create knowledge products for your customer



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Cognitive Performance Indicators

How do we apply CSE research to Assess Systems?

- Depends on the evaluator's experience/knowledge
- Many different approaches are used
  - From sitting a user at a screen and saying "what do you think?"…
  - ….to well-scripted scenario-based Cognitive Wall Walks

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Usability Professionals

- Have a set of Heuristics to use in assessment
  - Heuristics condense years of research into a concise, reference able list
- Use the Heuristics to identify issues and shortcomings

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Overview: Heuristics for Cognition

- Examined criteria from usability, ergonomics, human factors, accessibility, and learnability
- Towards the goal of assessing whether a system supports users' cognitive performance in naturalistic settings.
- Existing criteria did not support—needed newly developed indicators
- Identified the similarities in how CSE experts describe systems that support and hinder cognition in naturalistic settings
  - Review resulted in a set of 9 CSE-specific indicators.

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Heuristics for Cognition: Cognitive Indicators

1. Option Workability
2. Cue Prominence
3. Fine Distinctions
4. Direct Comprehension
5. Transparency
6. Historic Information
7. Situation Assessment
   - Enabling anticipation
8. Directability
9. Flexibility in Procedures
   - Adjustable Settings

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Cognitive Indicators

1. Option Workability: Systems should enable users to quickly determine if an option is workable.

2. Cue Prominence: Systems should allow users to rapidly locate key cues from the information presented.

3. Direct Comprehension: Systems should allow users to directly view key cues rather than requiring users to manually calculate information to comprehend these cues.

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Cognitive Indicators, cont.

4. Fine Distinctions: Systems should allow users to investigate or at least access unfiltered data.

5. Transparency: A system should provide access to the data that it uses and show how it arrives at processed data.

6. Historic Information: Systems should capture and display historic information so that users can quickly interpret situations and diagnose problems.

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Cognitive Indicators, cont.

7. Situation Assessment: Systems should help users form their own assessment of a situation rather than provide decisions and recommendations.
   - Enabling Anticipation: Systems should provide information that allows users to anticipate the future states and functioning of systems.

8. Directability: Systems should support the directing and redirecting of system priorities and resources so that users can effectively adapt to changing situations.

9. Flexibility in Procedures: Systems should allow users to modify the order of procedures as doctrine changes or situations call for flexibility.
   - Adjustable Settings: Systems should allow users to refine and adjust settings as they learn more about a situation.

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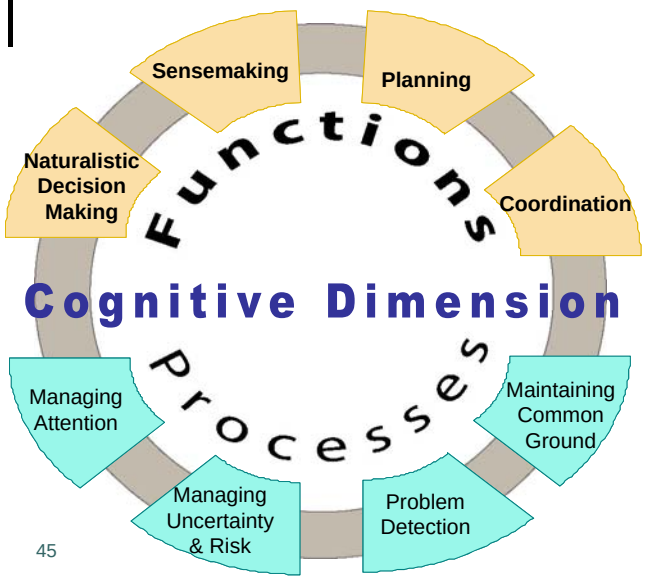
…back to Macrocognition



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Relevance to CSE

- The first step in CSE is to understand the problem space: Domain, People, Systems
- Cognitive Indicators help you see what's going on:
  - Act as a filter for identifying strengths/issues in how well technology supports work

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Using Cognitive Indicators

- Experience so far:
  - Evaluating National Weather Service system
  - Evaluating Hospital system for preventing 'Divert'
  - Organizing results of large-scale test event
- Could be used to identify system deficiencies and strengths with subject matter expert
- Each use requires tailoring list to most relevant indicators

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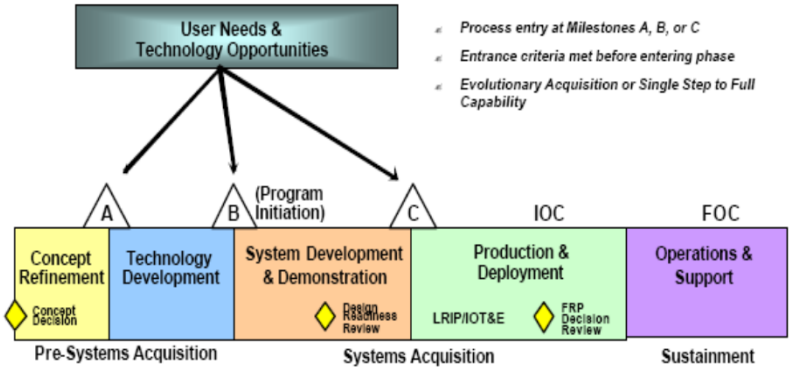
Where to Use the Indicators



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Redesigning the Data Collection

Redesigning the Data Collection

- Premise: Run another IMX
- Observation: What to observe more closely?
- CDM Interview: What probes to add?
- Other Data Collection Activities?

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CSE Bibliography; Wrap Up

Potential benefits of CSE

- Increased system performance.
- Reduced risk of additional iterations, project cancellations, rejected deliverables.
- Reduced time for software development.
- Lower training, personnel and manpower costs.

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Misleading claims about CSE

- CSE should support the systems engineering community.
  - It should also support program managers and sponsors.
- CSE is a strategy.
  - Variety of methods and tools available.
- CSE should minimize the user's cognitive requirements.
  - This moves towards passive users.
- CSE is a way to get the user's opinions into the design process.
  - Concern is for user's cognitive requirements, not opinions.
- CSE is essential to good system design.
  - Many good systems never involved CSE. But they managed to support cognitive requirements.

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CSE Methods to Use

- Observation Methods
- CTA interview
- Decision Requirements Tables
- Macrocognition Model
- Cognitive Indicators

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Cognitive Systems Engineering References

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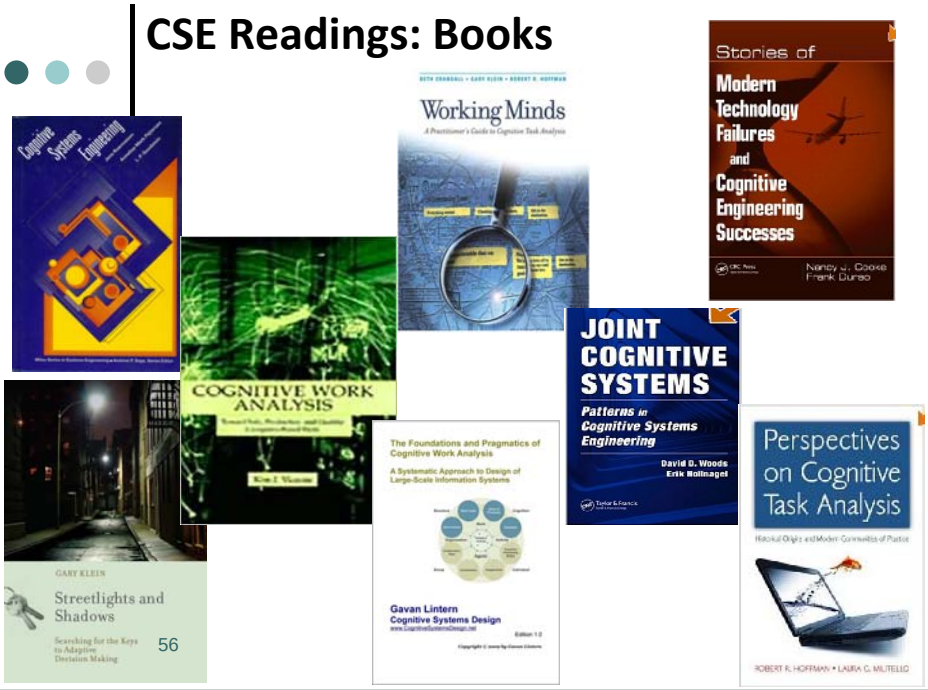
CSE Readings: Books



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