A Hybrid Approach to Cognitive Engineering: Supporting Development of Revolutionary Warfighter-Centered Command and Control Systems

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Continuum of Change

**Minor Change**
- C2 structure left intact
- C2 systems slightly altered
- New user front-end

**Evolutionary Change**
- C2 structure left intact
- C2 systems redesigned
- New user front-end
- Changes to back-end

**Revolutionary Change**
- C2 structure redesigned
- C2 systems redesigned
- New user front-end
- New back-end
- New work structure

**Minor Change**
- Many cognitive systems engineering methods available

**Evolutionary Change**
- Some cognitive systems engineering methods available

**Revolutionary Change**
- Very few cognitive systems engineering methods available
Effects-based Decision Analysis Methodology (EDAM)

• Designed for revolutionary change
• Based on cognitive engineering methodologies
  – Scenario Based Design
  – Cognitive Work Analysis
  – Situation Awareness Analysis
  – Cognitive Task Analysis
  – Team Cognitive Task Analysis
  – Use Cases
  – Storyboarding

Multiple methods to meet complete system design
Effects-based Decision Analysis Methodology (EDAM)

Iteration is the rule not the exception
Scenario Design

- Provide context
- Textual and/or graphical
- Used for structure throughout EDAM from knowledge elicitation through human performance evaluations
Work Domain Analysis

- Defines a work domain’s goals and constraints
- Often portrayed by a combined abstraction hierarchy and system decomposition
- Updated and refined throughout EDAM to reflect current design and ensure that design concepts meet the high-level goals

<table>
<thead>
<tr>
<th></th>
<th>Whole System</th>
<th>Subsystem A</th>
<th>Subsystem B</th>
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</thead>
<tbody>
<tr>
<td>Functional Purpose/Goal</td>
<td></td>
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<tr>
<td>Abstract Function</td>
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<td>Generalized Function</td>
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<td>Physical Function</td>
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<tr>
<td>Physical Form</td>
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</table>
Control Task Analysis

- Describes means of controlling or interacting with work domain
- Independent of agent (human or machine)
- Can be used to aid in the completion of a function/task allocation matrix

Cognitive Work Analysis
Goals
What are your specific goals at this time?
How do you prioritize these goals? Are there conflicts?
How does the outcome of a particular goal influence the success of your prioritization/reprioritization of the other goals?

Decisions
In this event in the scenario, what are the key decisions you are making?

Information Requirements
In this situation, how would you go about making the required decisions, what would cue you?
What information would you seek?
Can you get this information? Is it currently available?
Who would interact with you?
What ambiguities would you try to resolve?

Errors
What type of errors are likely at this point? In this decision?
What makes this difficult?

Situation Awareness – ability to respond
How do you maintain SA, what are you looking for, where does it come from?

Response
What is the effect of the decision? To whom are you providing information and action cues?
Who needs to know your decisions, information generated?

- Structured by scenarios
- Focused on goals and decisions as opposed to current methods or systems
- Interviews with Subject Matter Experts, in groups and individually
Decision Knowledge Elicitation

- Goal Directed Task Analysis
- Decomposes to increasing levels of detail

Derives requirements for decision support system design

Situation Awareness Analysis
Work Environment
Knowledge Elicitation

• Field observations and ethnographic studies of C2 operations, exercises, and/or training
• Focus on work in context – environment, layout of physical space, equipment, formal and informal social organization, communication
• Possible steps to follow for timeliness:
  – Review doctrine prior to exercise or observation
  – Observe work in actual work environment
  – Conduct post-observation interviews with observed subjects

Derives requirements for complete system design

Team Cognitive Task Analysis
Knowledge Organization and Representation

Activity Diagram

Function Allocation Matrix

<table>
<thead>
<tr>
<th>Function 1</th>
<th>Function 2</th>
<th>Function 3</th>
<th>......</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human 1</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Human 2</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Agent 1</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Agent 2</td>
<td></td>
<td>X</td>
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<td>...........</td>
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Abstracts knowledge gained in field observations
Technology Trade-Off Study

- Led by software/hardware development team
  - Consider future and near-future technologies

- Input from EDAM team
  - human roles
  - human factors
  - usability
  - supportability

Selecting the optimal technology (cost/performance trade) to support decision making
• Use Cases in UML
  – Operational aspects of the design
    • what the system does
    • how the human interacts with the system

• Storyboards and Paper Prototypes
  – Graphical User Interface concepts
    • information architecture
    • interactions
    • navigation
    • graphics
• Concurrent with decision support system design

• Complete system design
  – physical work environment
  – organizational structure
  – policies and procedures
  – software/hardware

• Supported by workload modeling and simulation

Supports all aspects of decision making
• Levels of prototyping
  – Storyboards and requirements animation (EDAM team)
  – Rapid, incremental, and evolutionary (S/HD team)

• Uses
  – Translate requirements from EDAM to SD team
  – Human performance assessments
    • cognitive walkthroughs
    • usability testing

Enables iterative evaluate/testing of system design
Human Performance Assessment

• Performed frequently throughout EDAM
  – Identify early as part of requirements analysis, validate metrics using prototypes and modeling & simulation
  – sparse scenarios to detailed paper prototypes to software development prototypes

• Metrics developed as appropriate to the system
  – successful and timely completion of tasks
  – time spent on errors, number of errors
  – number of actions used to complete task
  – number of regressive behaviors
  – subjective user evaluations

Provides technical performance measures for the human element of the system
EDAM address the human element in C2 design and fills the gap in revolutionary change.
QUESTIONS?
## Decision Knowledge Elicitation

<table>
<thead>
<tr>
<th>Probe</th>
<th>Things to consider asking if SME is having hard time identify decisions/information requirements</th>
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<tr>
<td><strong>Goals</strong></td>
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<tr>
<td>what were your specific goals at the time?</td>
<td>does this scenario fit a standard or typical scenario?</td>
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<tr>
<td>How did you prioritize these goals?</td>
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<tr>
<td>Are there conflicts?</td>
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<td>how does the outcome of a particular goal influence the success of or your prioritization/re-prioritization of other goals?</td>
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<tr>
<td><strong>decisions</strong></td>
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<tr>
<td>in this event in the scenario what are the key decisions you are making?</td>
<td>did this scenario remind you of any previous case or experience?</td>
</tr>
<tr>
<td>what decisions would you actually make?</td>
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<tr>
<td>what would cause you to make a decision at the time it was made</td>
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<tr>
<td>what decisions would be considered but deferred/why?</td>
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<tr>
<td>would any decisions be made in collaboration with other staff?</td>
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<td>would any decisions made require review and approval</td>
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<td><strong>information requirements</strong></td>
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<td>in this situation how would you go about making the required decision, what would cue you,</td>
<td>how do you communicate with external teams (i.e. SOF), particularly in Event 3?</td>
</tr>
<tr>
<td>what information would you seek,</td>
<td>how do you combine information to aid in decision making?</td>
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<tr>
<td>can you get this information? Is it available?</td>
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<td>who would you interact with,</td>
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<td>who are you talking to, what displays/systems do you use?</td>
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<td>what the effect of the decision, who are your providing information, what are the action cues to respond</td>
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