

# The Role of Meta-Information in C2 Decision-Support Systems

**Command and Control Research and Technology Symposium:**  
Cognitive and Social Domain Issues – Track 6

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# Overview

- General Motivation and Goals
- Approach and Methods
- Description of Domains
- Results of Analysis
- Implications and Conclusions



# General Motivation

- Interest in uncertainty w.r.t. system design & development
  - In Artificial Intelligence community
    - Probabilistic reasoning techniques
    - Representational formalisms
  - In Cognitive Engineering community
    - In decision-making (e.g., trust and uncertainty)
    - For visualization and interface design
  - In Military environments
    - Asymmetric warfare
    - Increase in HUMINT
    - Increase in information in NCW
  
- Anecdotes across many domains...



# General Motivation

- **“Uncertainty” is not enough**
- Information may be qualified in other ways
  - Importance, Quality, Impact, Pertinence
  - Recency, Staleness, Timeliness
  - Ambiguity, Accuracy, Precision
  - Pedigree, Confidence, Reliability
  - ...
- **“Meta-Information”**
  - ... is a concept/term that captures information qualifers more generally



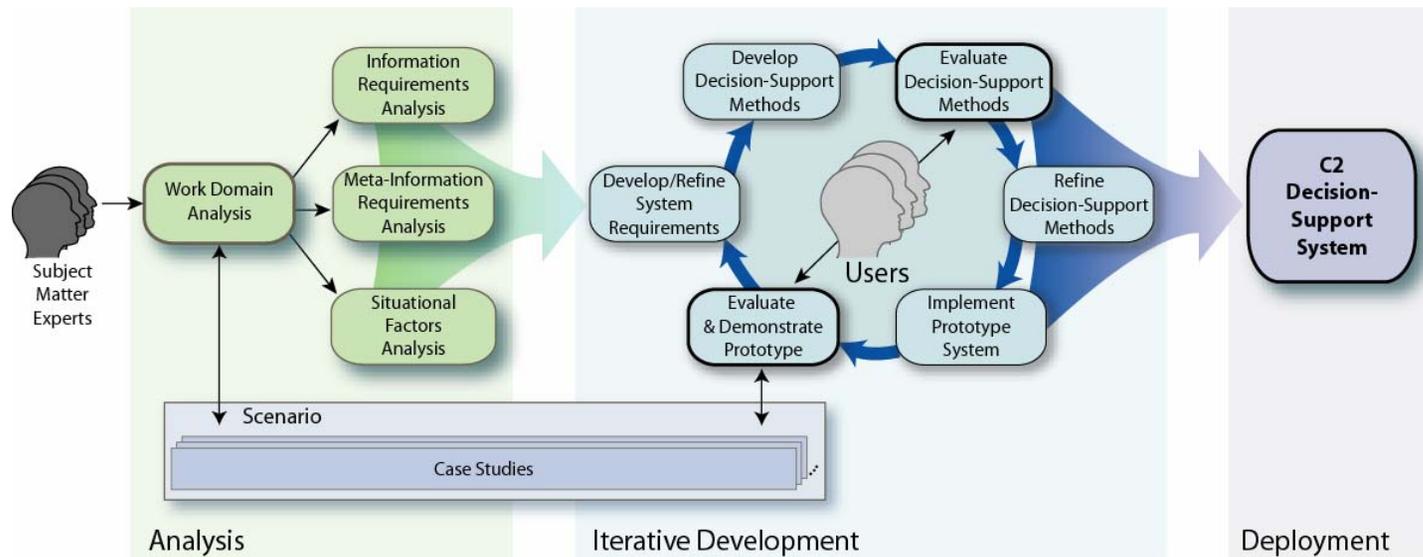
# Goals

- Establish that meta-information must be considered in C2 system design by summarizing analyses across C2 domains
- Provide guidelines to support the design of C2 decision-support systems w.r.t. meta-information
  - Displays and user interfaces
  - Computational methods
- Encourage design processes that aid in understanding meta-information requirements
  - Because of task and context dependence of meta-information



# Analysis Method

- o Performed analysis as part of Cognitive Systems Engineering methodology



# Analysis Approach

- Constructed hypothetical scenarios to explore context
- Conducted structured interviews with domain experts
- Performed analysis to:
  - Identify key sources of complexity and types of decisions
  - Uncover sources and types of:
    - Data
    - Meta-data
    - Information
    - Meta-information
  - Identify required information and meta-information
  - Discover situational influences on requirements



# C2 and C2-Related Domains Analyzed

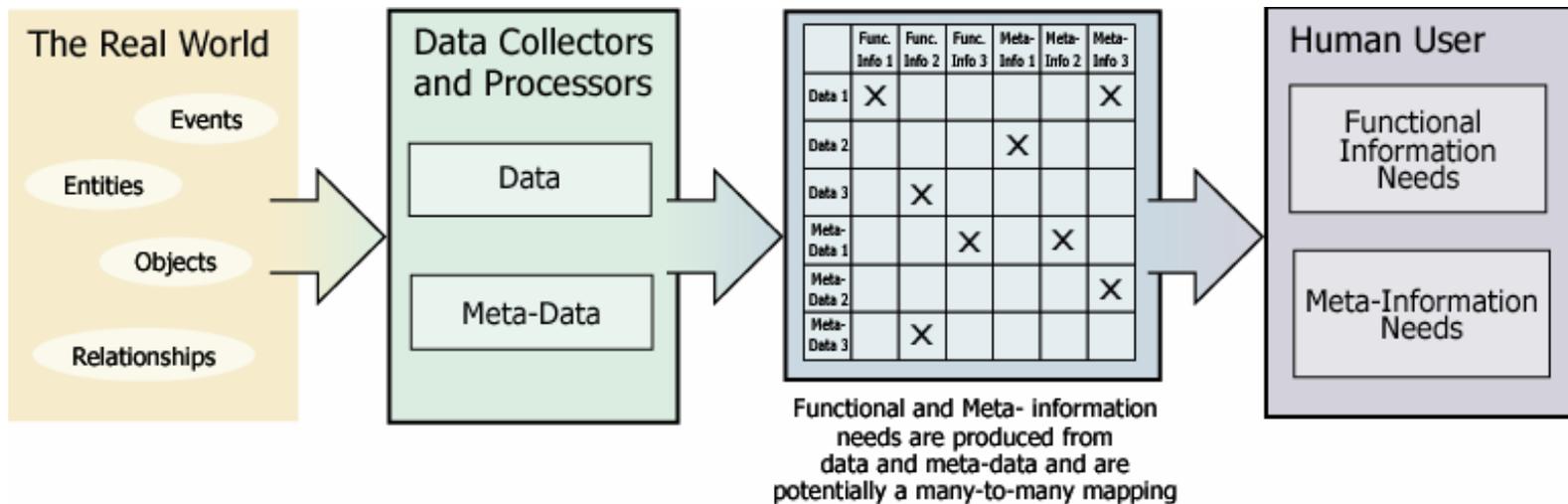
- Intelligence operations
- Small-unit tactical maneuvers
- Sensor management
- Weather impact assessment
- Natural disaster management

(Our thanks to the many domain experts we interviewed and observed!)



# Results of Analysis

- Identified information needs
- Identified meta-information needs
- Defined meta-information concepts



# Working Definitions

- **Data**: output (processed or unprocessed) from a human or machine system – e.g.,
  - Acoustic sensor X reports 34 Db
  - Joe says it is raining
- **Information**: an input to a directed decision-making process – e.g.,
  - A storm is coming, thus I will not launch the weather balloon until tomorrow
- **Meta-Data**: characteristics or qualifiers of data – e.g.,
  - Temperature sensor Y has an error of +/- 0.1 deg F
- **Meta-Information**: characteristics or qualifiers of information, affecting a human's:
  - Information processing
  - Situational awareness
  - Decision-making
  - E.g., There is a 60% chance the fire is located at {x,y} therefore I will confirm its location before sending fire trucks



# Definitions, cont'd

- Is “meta-information” just “information”? No.
  - It *qualifies* information
  - It may be reasoned about differently
    - E.g., qualifiers may be ignored under high time demands
  - It tends not to be regularly captured or represented in many human-machine systems where it is needed
- How we might define data, meta-data, information, and meta-information depends on
  - The decision-making task
  - The context or situation



# Meta-Information Definitions across Tasks

	Sensor Management	Tactical Decision-Making
Data	Sensor X reports 42.2 dB Sensor Y reports 32.1° F	Sensor X reports 42.2 dB Sensor Y reports 32.1° F
Meta-Data	Sensor X error is $\pm .4$ dB Sensor Y reports at 5 Hz	Sensor X error is $\pm .4$ dB Sensor Y reports at 5 Hz
Information	Location of sensors Sensor types "Health" of sensors	Location of targets Type of targets Number of targets
Meta-Information	Accuracy of sensor status Recency of sensor status	"Health" of sensors Coverage of sensors Accuracy of target information Recency of target information



# Meta-Information Definitions across Tasks

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<b>Information</b>	Location of sensors Sensor types <b>“Health” of sensors</b>	Location of targets Type of targets Number of targets
<b>Meta-Information</b>	Accuracy of sensor status Recency of sensor status	<b>“Health” of sensors</b> Coverage of sensors Accuracy of target information Recency of target information



# More Results

- Analyses showed wide range of types of meta-information
- The following provide examples of meta-information types we encountered...



# Types of Meta-Information Discovered

- Characteristics of the source of the information
  - Type of data the source can produce
  - Type of processing used
  - Range of data generated
  - Baseline error rates
  - Frequency of reporting
  - Ability to report on its status and characteristics of that report
  - Inherent biases
  - Past performance, history
  - Directly observing or deriving information



# Types of Meta-Information Discovered

- Characteristics of the source varying with other information
  - Time
  - Location in environment (e.g., terrain, weather)
  - Types of intermediate processing
  - Content of report
  - Information context
- Uncertainty
  - Spatial uncertainties
  - Temporal uncertainties
  - Uncertainties about uncertainty reporting
  - Likelihood
  - Probability
  - Confidence
  - Accuracy
  - Precision



# Types of Meta-Information Discovered

- Ambiguity
  - Specificity or resolution of information
  - Level of abstraction of information
- Information context (i.e., relationship to other information)
  - Degree of confirming or disconfirming information
  - Paucity of information
  - Frequency of reporting of information
  - Missing or degraded information qualifiers
  - Information-to-noise ratio
  - History
- Reliability of source
  - W.r.t. source characteristics
  - W.r.t. information context



# Types of Meta-Information Discovered

- Credibility of content from source
  - W.r.t. reliability
  - W.r.t. type of content
  - W.r.t. type of source
  - W.r.t. information context
- Relevance or pertinence
  - W.r.t. specific mission goals
  - W.r.t. actual/perceived information needs
  - W.r.t. broader operational context
  - W.r.t. current hypotheses about the situation
- Temporal qualifiers
  - Staleness
  - Recency
  - Certainty about time of reporting
  - Latency
  - Lag
  - Absence of expected information



# Meta-Information and C2 Decision-Making

- Uncovered three complexities related to decision-making and meta-information
  - Failure to recognize relevant meta-information
  - Failure to process meta-information appropriately
  - Failure to properly utilize meta-information
- These complexities apply to both
  - Human decision-making
  - Machine reasoning



# Implications & Future Work: Computational System Design

- Need to represent meta-information needs in data structures, computational processes
- Need to calculate meta-information from data and meta-data
- Need to aggregate meta-information
- Need to process types of meta-information simultaneously
- Need to minimize impact of additional computation
  
- Future work:
  - What representational formalisms are amenable to handling multiple types of qualifiers?
  - What computational processes support reasoning over qualified information?
  - To what extent can existing methods be adapted to support meta-information needs?
  - ...



# Implications & Future Work: Display and Interface Design

- Need to communicate meta-information in a situation- and task- relevant manner
  - What visualization methods work for what types of meta-information?
  - How does the information type and its display method interact with the meta-information visualization?
- Need to avoid overloading the user with the presentation of meta-information
  - How and when does the presentation of meta-information cause overload?
  - What user interface mechanisms could aid in avoiding overload?
- Need to aid reasoning about and with meta-information
  - What displays/UIs facilitate a user's ability to understand and exploit meta-information?
  - How can users be trained to recognize and use meta-information?



# Conclusions

- We must go beyond thinking only about uncertainty
  - Information may be qualified in many ways
- Meta-information needs should be reflected in C2 decision support systems:
  - As part of underlying computational methods
  - As part of displays and interfaces
  - With awareness of task and situation dependencies
- Additional work remains to be done...



# Questions?

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