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NORTH CAROLINA A&T STATE UNIVERSITY

THEORY AND EVALUATION OF BATTLEFIELD VISUALIZATION IN CONTEXT

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This project is supported by ARO grant #W911NF-04-2-0052 under Battle Center of Excellence initiative. The opinions presented here are not those from ARO, and are solely those of the authors.

Presentation Outline

1. INTRODUCTION: WHAT IS VISUALIZATION?
2. THEORY OF INFORMATION VISUALIZATION
3. BATTLEFIELD VISUALIZATION
4. VISUALIZATION AND HUMAN ACTIONS
5. EXPERIMENTAL STUDY
6. RESULTS
7. SUMMARY & CONCLUSIONS

What is Visualization?

•To form a mental image (the American Heritage College Dictionary).

•The use of interactive visual representations of data to amplify cognition (Card, et al., 1998).

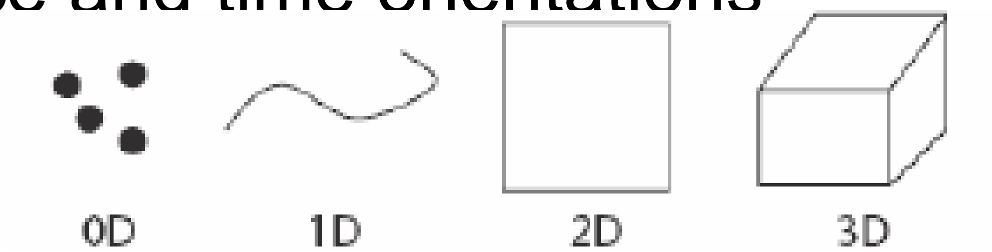
•Skillful use of images (Koffka, 1935: Principles of Gestalt Psychology)

•A mental process of developing situational understanding, determining a desired end state, and envisioning how to move [from one state of a system to another]– FM3-0:Full spectrum operations, DoD

Two Main Types of Visualization

•Scientific Visualization:

- ❑Display of data using their statistical (and other mathematical) properties such as correlation, mean, standard deviation, etc.
- ❑ Involves both space and time orientations



Isosurfaces, volume rendering, and glyphs are commonly used techniques

Isosurfaces depict the distribution of certain attributes

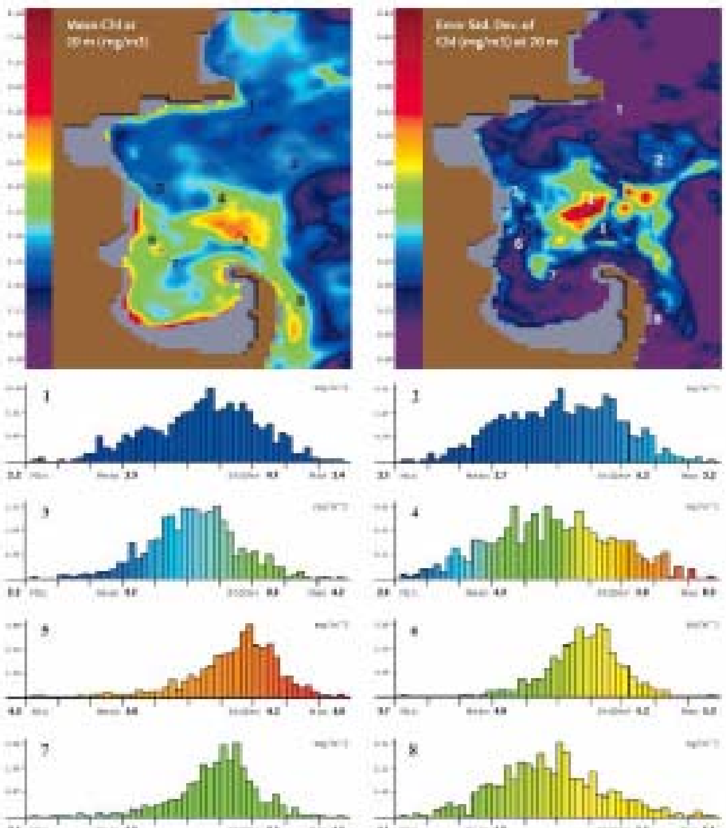
Volume rendering allows views to see the entire volume of 3-D data in a single image (Nielson, 1991)

Glyphs provides a way to display multiple attributes through combinations of various visual cues (Chernoff, 1973)

Two Main Types of Visualization

- Allows analysts to view information in multiple dimensions and scales.
- Scaling effect may be intolerant to meaningfulness of information in context

•Scientific Visualization:



Chlorophyll mean and uncertainty of the Massachusetts Bay data set

Lermusiaux P.F.J., C.-S. Chiu, G.G. Gawarkiewicz, P. Abbot, A.R. Robinson, R.N. Miller, P.J. Haley, W.G. Leslie, S.J. Majumdar, A. Pang and F. Lekien, 2006. Quantifying Uncertainities in Ocean Predictions. *Oceanography, Special issue on ''Advances in Computational Oceanography''*, T. Paluszkiewicz and S Harper, Eds., Vol. 19, 1, 92-105.

Scientific Visualization

- Bertin (1967) identified basic elements of diagrams in 1967
- Most early visualization research focused on statistical graphs (Card et al., 1999)
- Data explosion in 1980s (Nielson, 1991)
- NSF launched the "Scientific visualization" initiative in 1985
- IEEE 1st visualization conference in 1990

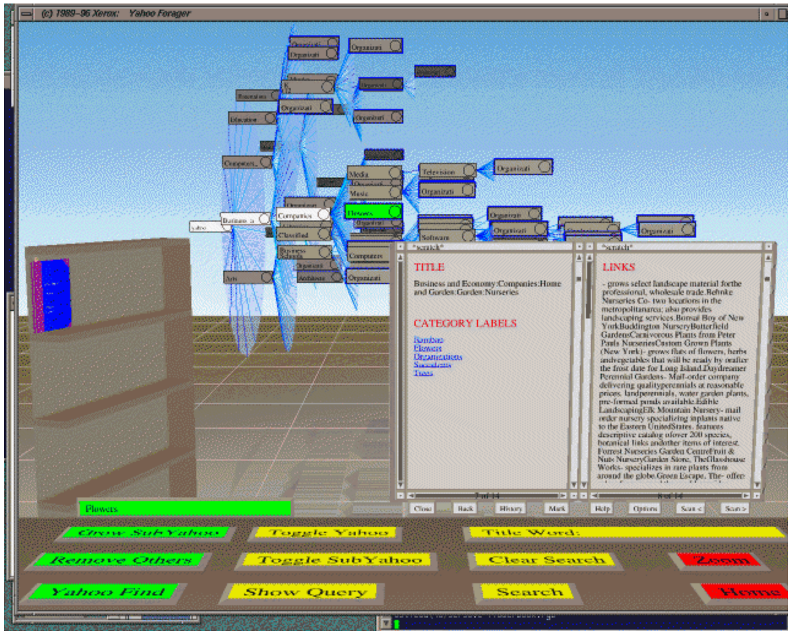
Information Visualization:

- Is the cohesive coupling of information characteristics and human cognitive processes

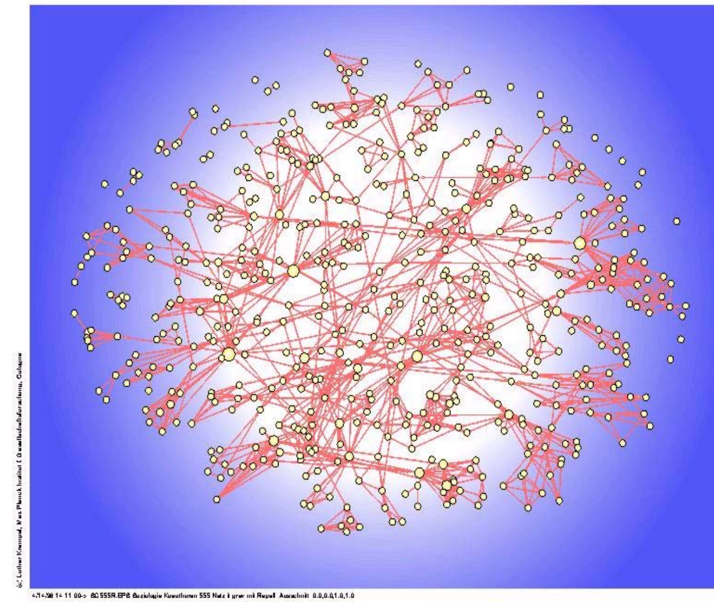
"information visualization" was first used in Robertson et al. (1989)

Early information visualization systems emphasized
- interactivity and animation (Robertson et al., 1993)
- Interfaces to support dynamic queries (Shneiderman, 1994)
- Layout algorithms (Lamping et al., 1995)

Information Visualization:



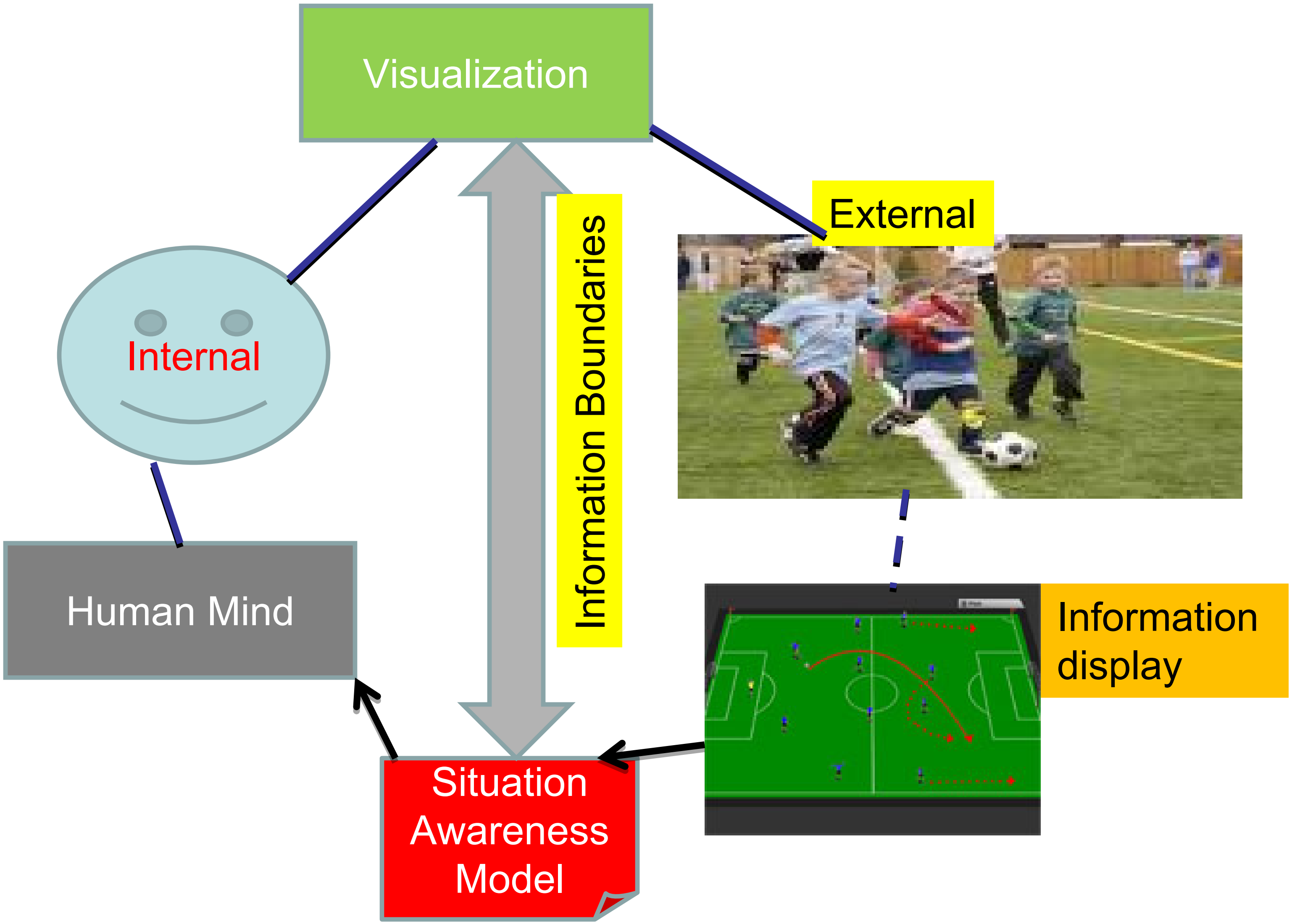
Cat-a-Con Tree(Hearst & Karadi, 1997)



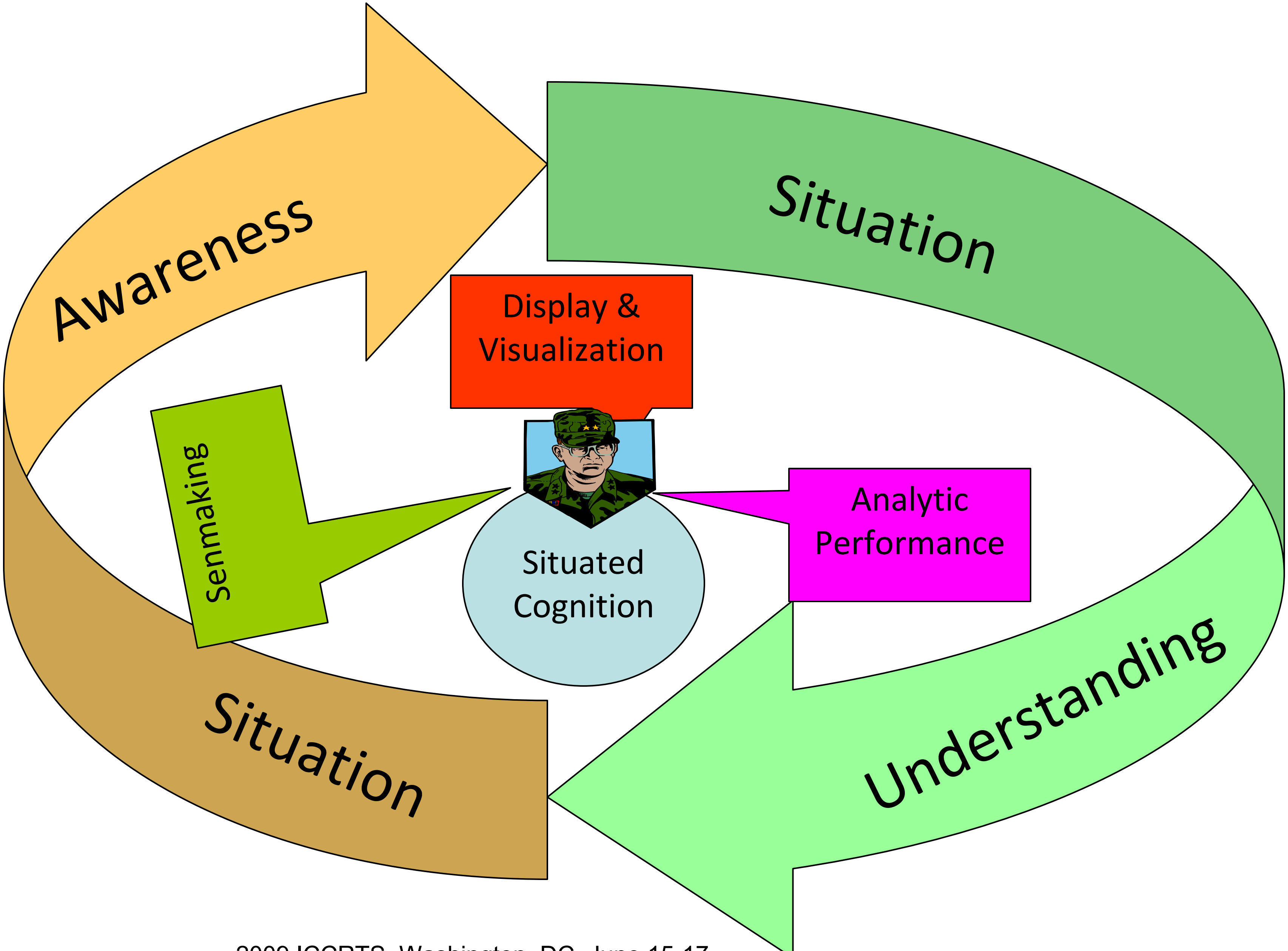
Visualization Tree
E.G., Social Network

THEORY OF INFORMATION VISUALIZATION

Visualization and cognition are embodied and situated



Visualization and cognition are embodied



Visualization and cognition are embodied and situated

- ❑ Embodiment
  - ➢ A coupling of perception-cognition-action cycle using sensory information in the form of signals, signs, and symbols.
  - ➢ Both visual elements and cognition form a knowledge artifact in context of task.

Visualization and cognition are embodied and situated

❑ Situated

➢ Situatedness (Clancey, 1997; Suchman, 1987) holds that "where you are, when you do, what you do matters". Thus, situatedness is concerned with locating everything in a context so that the decisions that are taken are a function of both the situation and the way the situation in constructed or interpreted.

THEORY OF INFORMATION VISUALIZATION

Theory of Mind (ToM):

- Visualization occurs internally in the mind (Searle, 1983)
- Visualization is externally mediated by ecological Information factors (Gibson, 1978).
- The mind is responsible for shaping meaningful spaces for situation understanding.
- The mind expresses visualization in terms of imagination, precepts, concepts, ideas, etc.

Internal Visualization: the Theory of Mind (ToM)

Wikipedia:

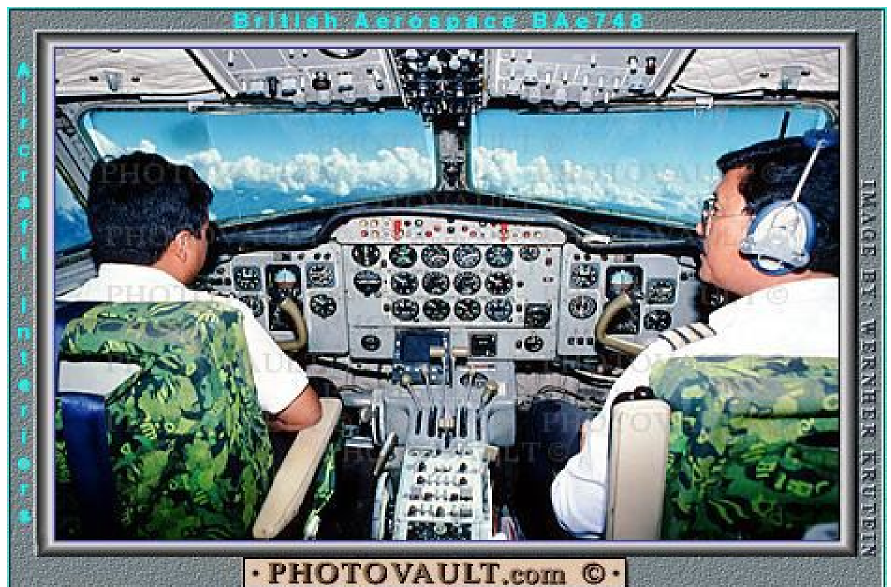
- The Mind collectively refers to the aspects of intellect and consciousness manifested as combinations of thought, perception, memory, emotion, will and imagination
- Mind is often used to refer especially to the thought processes of reason
- The mind is a model of the universe built up from insights

Thinking involves the cerebral manipulation of information

Internal Visualization: the Theory of Mind (ToM)

- It is by the eyes of the mind, by reasoning over the whole, by a species of inspiration that the general sees, knows, and judges (Napoleon Bonaparte)

- Visualization cannot be separated from the context in which the objects of displays and grounding knowledge for representation are derived (Schneiderman).



External Visualization: Ecological Approaches

- "Animal and environment make an inseparable pair"
(Gibson, 1979, p.8).

- "What you see when you see a thing depends upon what the thing you see is" (Fodor & Pylshyn, 1981)

Considerations for:

Space
Time
Distance
Dynamism such as movement and changes

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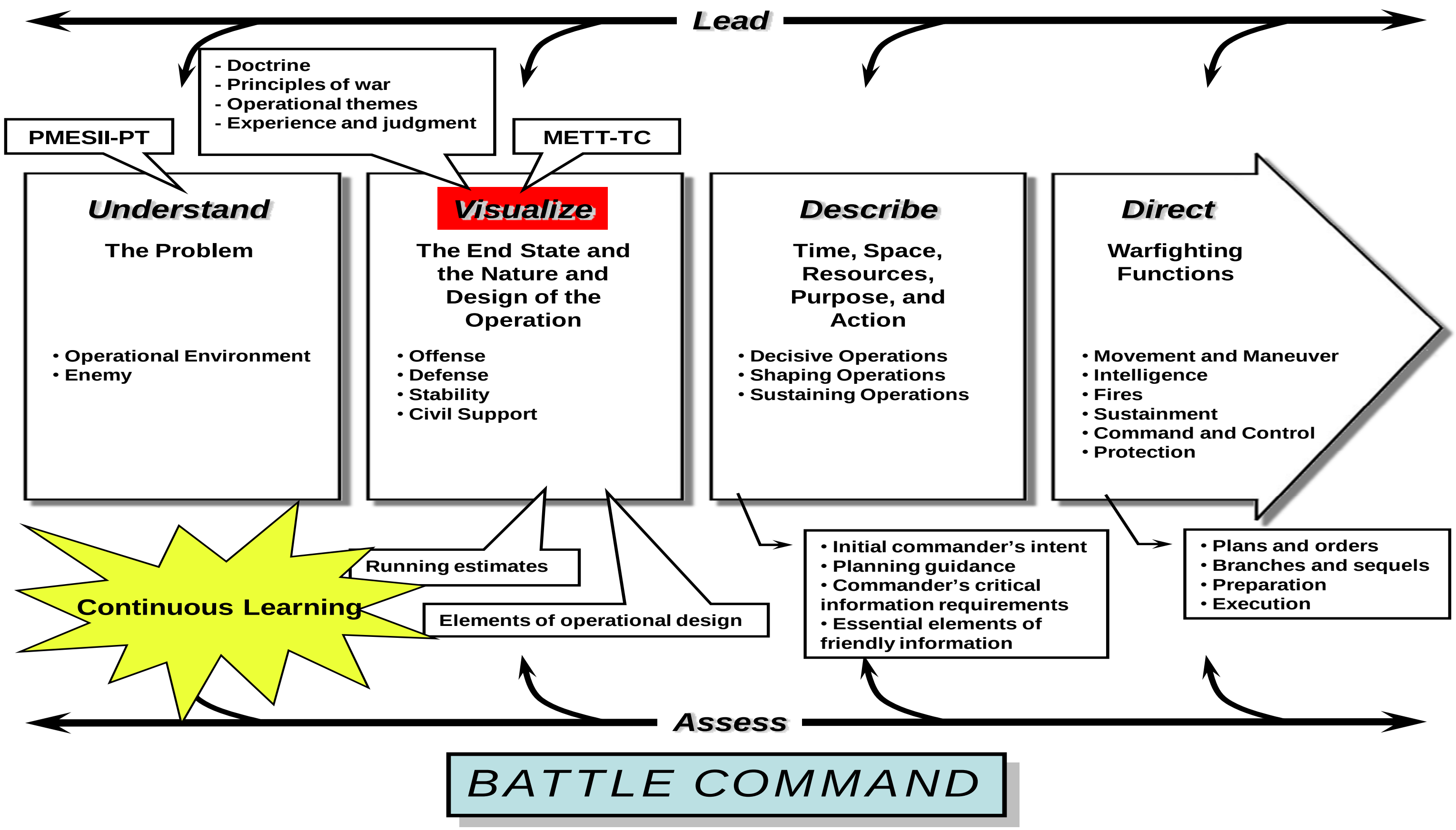
BATTLEFIELD VISUALIZATION—DOCTRINAL DRIVERS



According to Franks, battle command means seeing what is now, visualizing the future state or what needs to be done to accomplish the mission and then knowing how to get your organization from one state to the other at least cost against a given enemy on a given piece of terrain.

LTG. William S. Wallace (Military Review, May-June, 2005): *In the Battle Command concept, commanders use a personal decision-making process that incorporates visualizing the operation, describing the operation in terms of intent and guidance, and then directing actions within that intent.*

Army Transformation Road Map, 2003: Battle command includes visualizing the current and desired future states of friendly and enemy forces and then deciding how to get from one to the other at least cost.

FM 100-5: Battle command is the art of battle decision making, leading, motivating soldiers and units into action. It includes visualizing your current and future state.

Doctrinal Background

Army FM 6-0, Mission Command: Command and Control of Army Forces:

Visualization is a cognitive ability that creates mental images based on
(i) experience, training and education and knowledge of doctrines;
(ii) goals, the timetable for achieving them, and the desired end state to include mission and intent; and
(iii) resources and activities to achieve the goals

How Visualization Enables Human Action in Situated Contexts: Situation Awareness

Human endeavor	Visualization elements
Patterns {search, recognize, etc}	Data Cues
Attention {monitor, track, tag}	Information awareness
Knowledge discovery {predict, anticipate, relate }	Situation understanding
Judge (compare, evaluate, choose}	Decision Making

How Visualization Enables Human Action in Situated Contexts: Sensemaking and Information Fusion

Human endeavor		Visualization elements
How things are connected	↔	Relationships measures
Fitting the puzzle	↔	Finding information to fit the context; fitting data into frame (Klein, 1998).
Information fusion for common metric	↔	Information integration from multi-dimensional scales
Creating knowledge	↔	Using data to obtain information; information processed into knowledge

EXPERIMENTAL STUDY

Visualization Performance Factors (VPF)

1.Reference to a hybrid of covert visualization (ToM) and tacit knowledge (sensemaking)
2. Situation awareness guided by external and semiotic knowledge (information displays, symbols, signs, signals)

Objective:

❑Identity VPF and the relationships.

Approach:

❑Subjective data collection. Anecdotal and proof-of -concept

EXPERIMENTAL STUDY

Past Studies

1. Focus on situation awareness
2. Most study utilize self-rating subjective scales
    1. E.g., SABARS (Situation Awareness behaviorally Anchored Rating Scales—Strater, et al., 2001)
    2. PSAQ (Participant Situation Awareness Questionnaire—Mathews, et., 2000)
    3. SART (Situation Awareness Rating Tool (Taylor, 1990)

APPARATUS

SASOSIM: Stability and Security Operation Simulation

1. A simulation model developed from operational vignettes from Fort Leavenworth.
2. Run on Sensemaking Support System (S3) environment.
3. Allows a single or multiple users (up to 5) at the same time.

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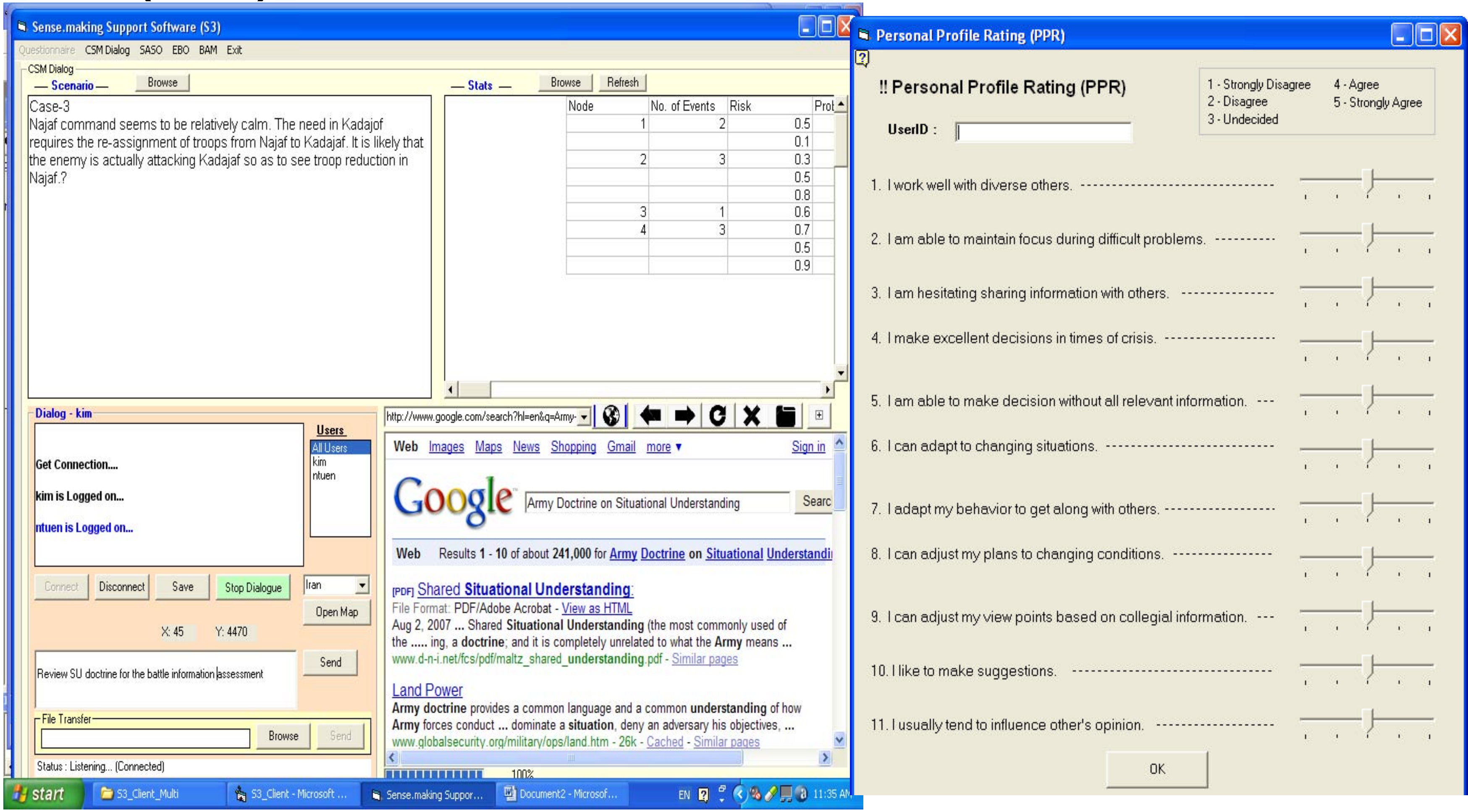
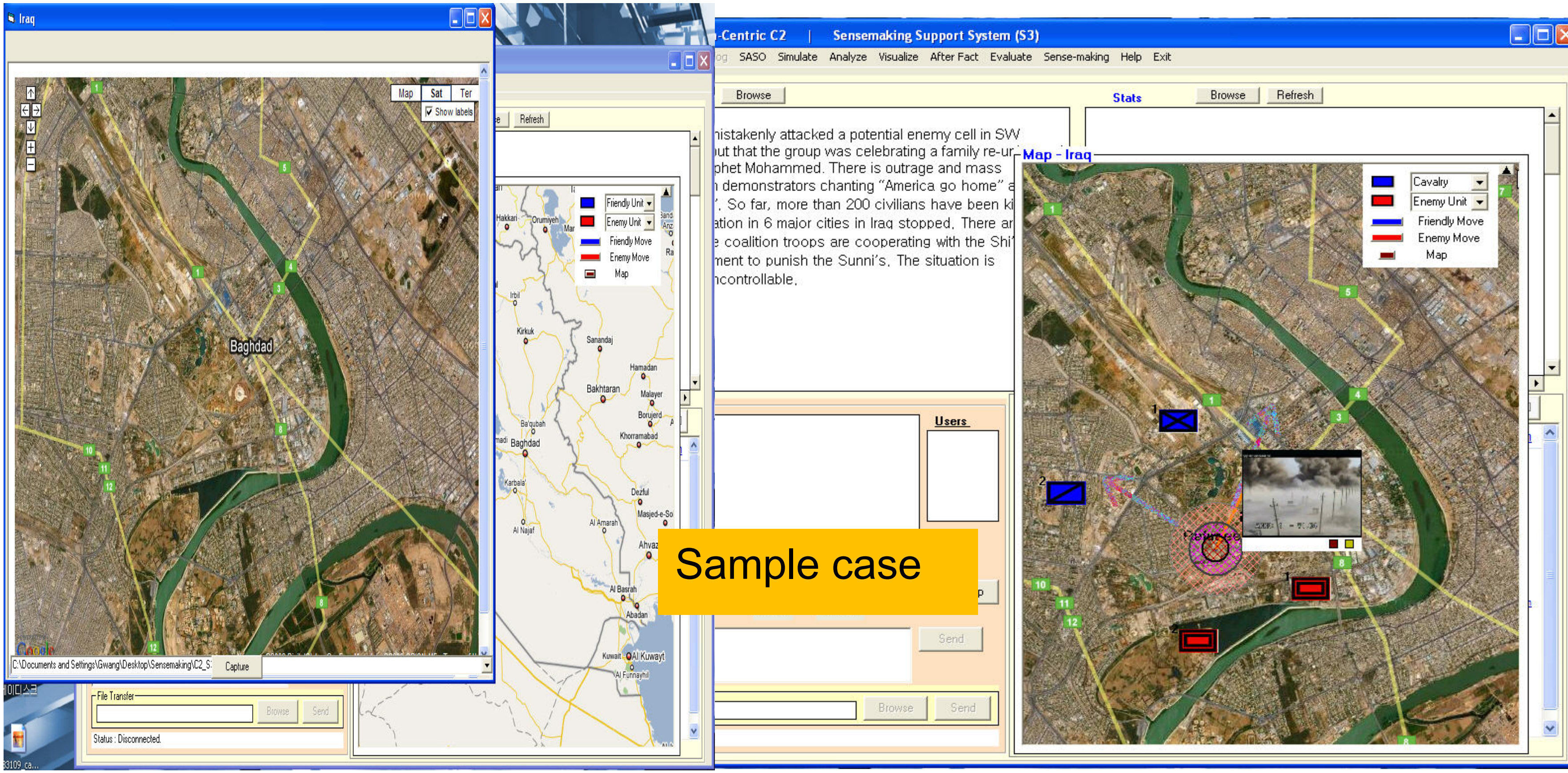
APPARATUS

Sensemaking Support System (S3) Visualization Software Tool



S3 Allows for Terrain Visualization Using Google Earth Map



2009 ICCRTS, Washington, DC, June 15-17

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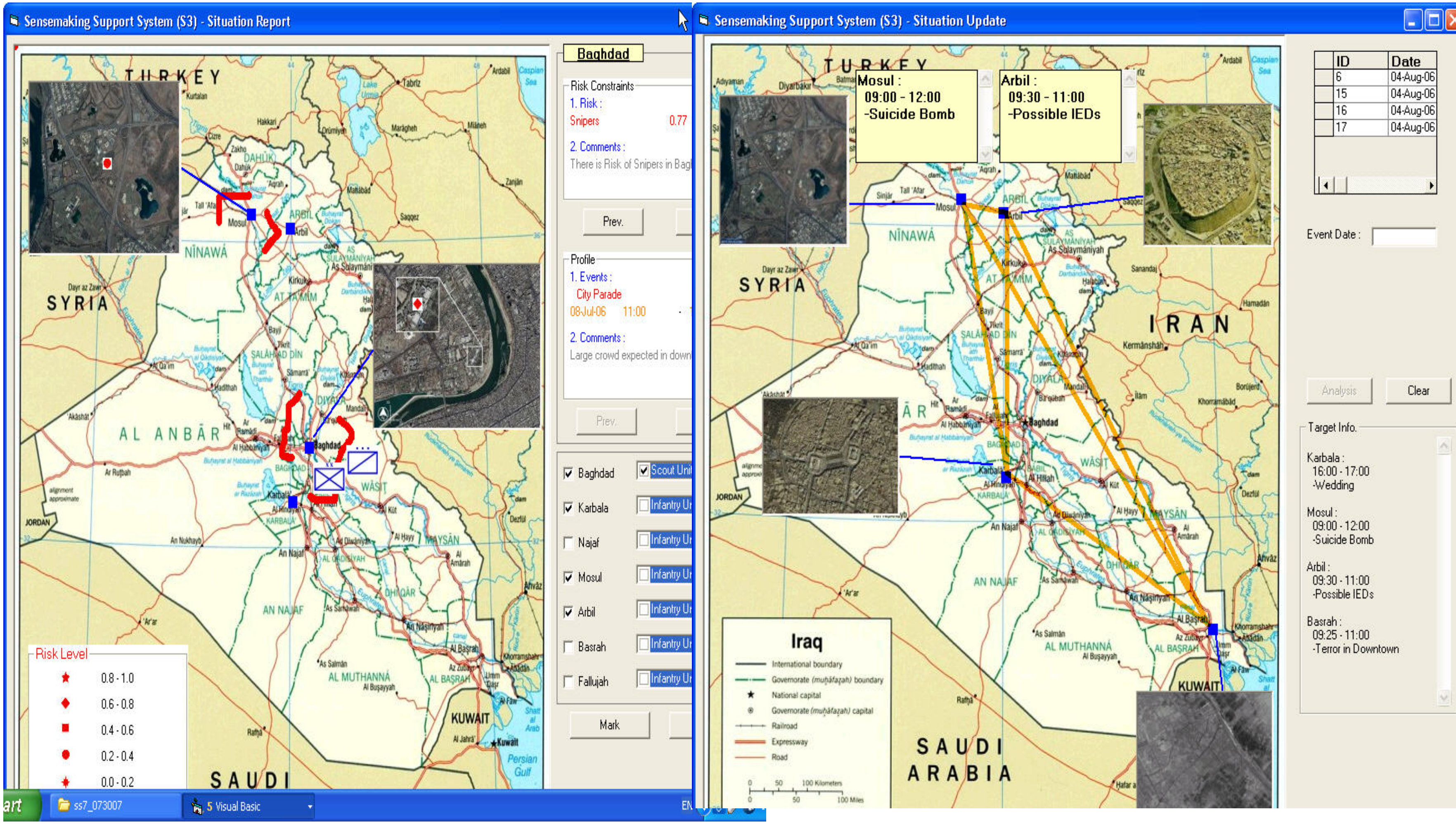
S3 Creates Retrospective Information Linkages (Right), and Allows the User to Use a Whiteboard to Mark Areas of Interest (Left)



Participants:

11 volunteered military officers

4 Army Reserve Training Corps (ROTC) from North Carolina A&T State University

5 Civilian (retired military) working at the university + Army

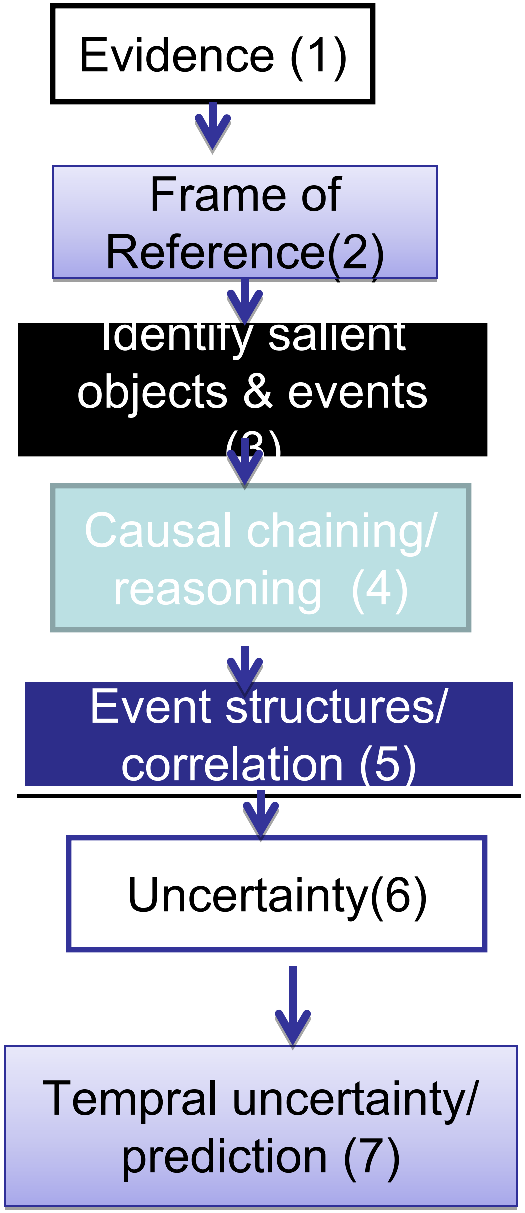
2. Reserve component in Greensboro

Combined military experience = 163 man years (std= 11.73)

Requirements:

- A rank of Lieutenant & above
- Experience as a commander from a platoon level and above
- Have combat experience in modern conflicts such as Iraq.

Approach to VPF Using Clauser and Fox Method



(1) A prior information in the form of texts, transcripts, videos, voice, etc: e.g., Al-Qaida footprints from satellite photos

(2) A set of hypotheses indicating other possible causal cues

(3) The types of weapons used and the locations of attacks

(4) Preaching in the mosque, staying home on a market day by some groups; Recruiting around the areas in which attacks occur.

(5) Mapping similar attack behaviors and profiles in different austere regions.

(6) Determining some clues about the states of agitation and pandemonium; Estimating the likelihood of volatile areas being attacked while ignoring possible attacks on stable regions.

(7) Uncertainties associated with temporal events and processes. E.g. unpredictable hit and run by sniper weapons, EIDs, and kidnapping.

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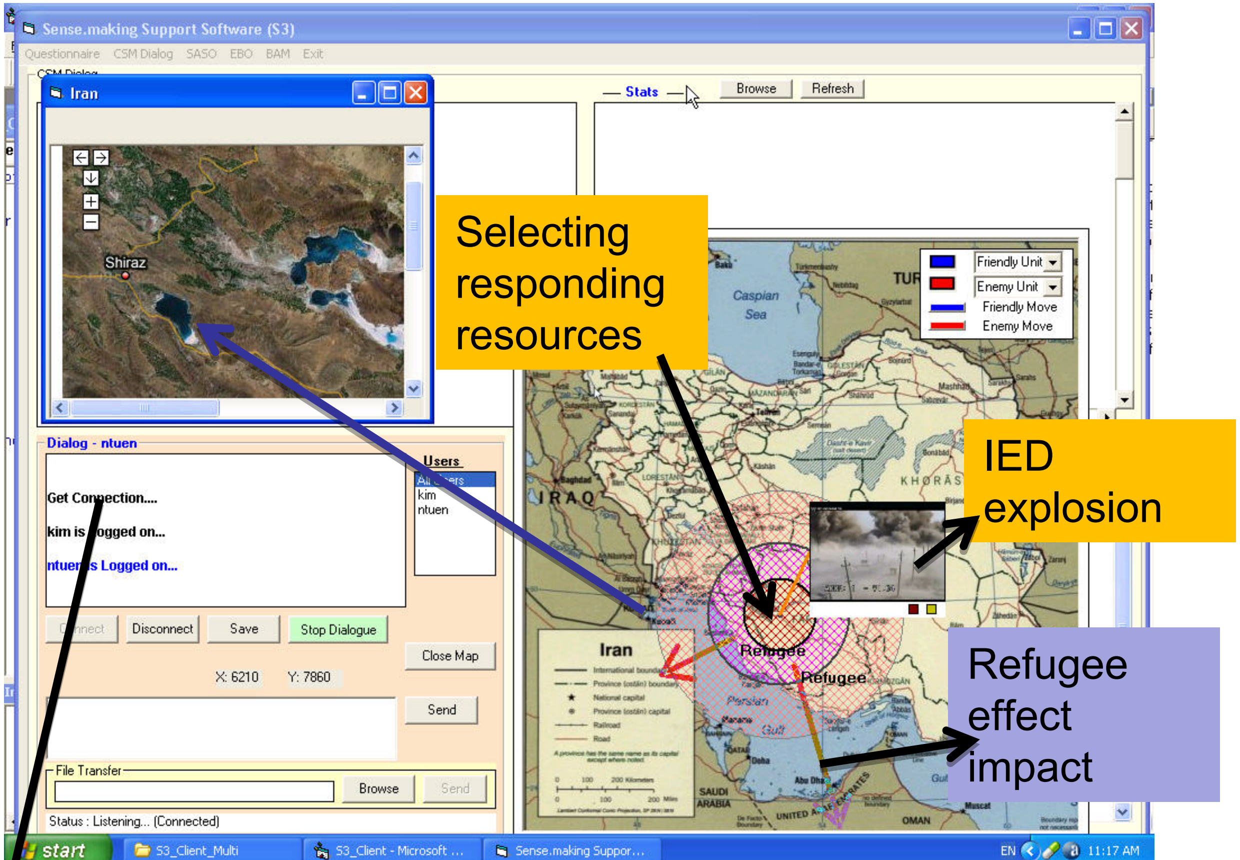
Procedure:

- Create a team of 2 subjects representing battlestaffs.
  - Possible 55-team pairs (11 permuted by 2)!!
- 35 pair-trials used due to scheduling problem
- Post experiment questionnaires administered to individuals separately.
- The study took 9 days of 1 hour per team
- The participants receive training on SASOSIM for sensemaking process.
- Events requiring emergency response were created (e.g, bombing, EID attack, etc) –see next slide.
- The team assessed the situation on each event:
  - Who is responsible?
  - When did it happen?
  - Who are responsible?
  - What are anticipated effects?
  - What are other likely targets



Expanded Information View of the Satellite Image

S3 Creates SASO incidents based on database selection

Visualization Performance Factors Analyzed—Post Experiment Survey

On a scale of 1 to 7 (1 = absolutely not useful and 7 = absolutely very useful) give rating to the following items based on the situation visualization and display and the tasks you are asked to perform:

X1: **Situation Understanding**: The ability to translate situation information into actionable knowledge for decision making.

X2: **Evidence**: The amount of evidential cues and clues provided and gained during the visualization process.

X3: **Frame of Reference**: The ease to which the display cues support and enable the development of plausible hypotheses related to the event causes.

X4: **Information Foraging**: The ease to which the visualization tool helps in information seeking and extracting for sensemaking.

X5: **Causal Chaining**: The ease to which the visualization tool helps to trace the causal linkages between the events and effects.

X6: **Team sensemaking**: The ease to which the visualization tool allows the team to collaborate.

X7: **Level-3 SA**: The ease to which the visualization tool allows the user to predict the future states of the situation and the effects.

X8: **Belief Revision**: The extent to which the visualization tool helps the sensemaker to change opinion and/or revise belief because of new information.

RESULTS

Three types of analyses:

1.Mean, standard deviations,
and inter-rater agreement (Williamson & Manatunga, 1997)

Except for causal chaining variable, all VPF show some agreement with corrected Fisher test criterion--- the subjects did not agree on the variable as a metric for VPF.

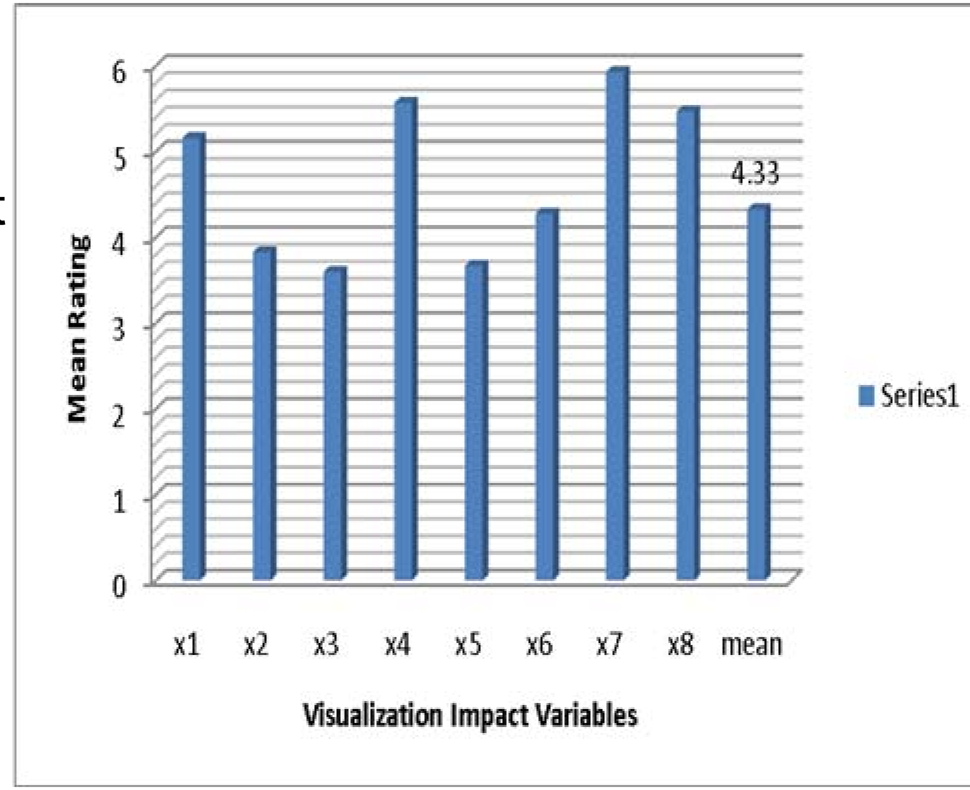
Criterion	Mean	Std	Inter-rater coefficient
SU (X1)	5.16	1.32	0.422
Evidence (X2)	3.83	1.51	0.367
FoF (X3)	3.6	1.33	0.417
Info. Forage (X4)	5.57	1.09	0.503
CC (X5)	3.67	1.62	**0.322**[a]
Team (X6)	4.28	1.28	0.435
SA-3(X7)	5.93	1.14	0.485
Belief (X8)	5.47	1.05	0.517

a: not statistically significant at $p < 0.01$

RESULTS

Three types of analyses:

1.With a two-pair Turkey test using the overall mean of 4.33 across all variables: Frame of reference and causal chaining were on significant at $p \leq 0.01$; All other PVF were significant at $p \leq 0.05$. Level III SA was prominently different indicating strong visualization measure; and so were information foraging and contributions to belief revision



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RESULTS

	X1	X2	X3	X4	X5	X6	X7	X8
X1								
X2	0.48							
X3	0.61	0.717						
X4	0.633	-0.416	??					
X5	0.688	0.34	??	0.816				
X6	0.739	0.672	-0.331	-0.643	??			
X7	0.802	0.445	??	0.381	0.428	0.726		
X8	-0.575	0.716	-0.359	0.353	0.315	-0.527	??	

?? Indicates non significant at $p \leq 0.05$

2. Correlation Analysis:

No statistical relationship between how people frame a problem and: (1) how they seek information; (2) the causal chain process used; and (3) team sensemaking.

Negative correlations: -0.416 between evidence and information raging indicates that there is no need for seeking further information once evidence is known.

Positive correlations: Indicates increasing relationship between variables

RESULTS

3. Prediction Equation for Situation Understanding:

SU (X1) = 2.3 + 0.42 Clues from SA (X2) + 0.16 Level III SA (X7)

$(1 \leq \{X1, X2, X7\} \leq 7)$
$p = 0.0003$
$R^2 = 0.837$

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SUMMARY AND CONCLUSION

Evaluation study is preliminary. There is an on-going study to develop a metric for sensemaking and visualization

Some notables:

The correlation value of -0.575 between situation understanding and belief revision indicates that as the individual achieves a better SU, the less likely that he/she will change an already hold opinion—pointing to availability bias which asserts that people use the available information in the memory to estimate what is more likely in a situation (Kahneman, et. al., 1999).

Individuals may NOT likely to change their beliefs once they are fixed on a set of hypotheses—confirming anchoring bias (Evans, 1989) which assert that people have the tendency to rely too heavily on retrospective knowledge during sensemaking.

Teams will NOT seek for further information once a consensus has been reached (-0.643 between information foraging and team sensemaking).