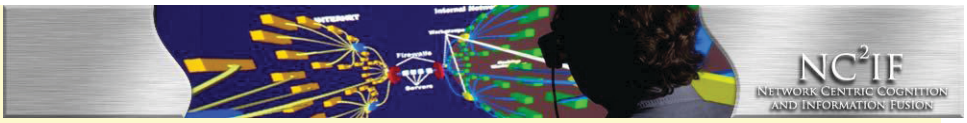

Human Centered Fusion: The Emerging Role of Humans in Situation Awareness

Keynote Address

May 8, 2010

David L. Hall
Director
Center for Network Centric Cognition & Information Fusion
The Pennsylvania State University

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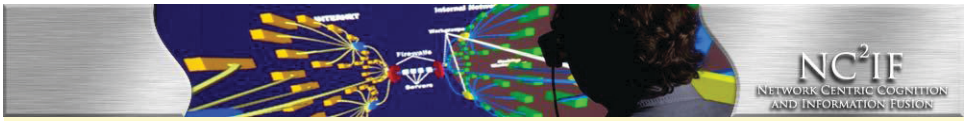
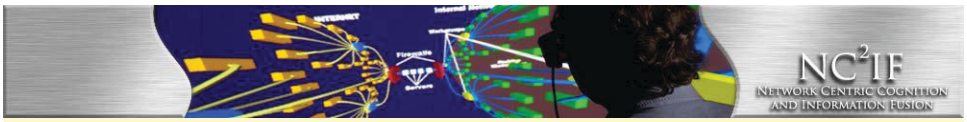


Presentation Topics

- Introduction to NC2IF
- Legacy of DoD information fusion
- Information fusion trends
- Concept of human centered fusion
- Research approach for hard/soft fusion
  - Experimental infrastructure
  - Theoretical framework
  - Initial algorithms and demonstrations
  - Evolving data sets
  - Technology transition approach
- Related projects
- Summary

2

Cyber Security, Situation Management, and Impact Assessment II; and Visual Analytics for Homeland Defense and Security II, edited by John F. Buford, Gabriel Jakobson, John Erickson, William J. Tolone, William Ribarsky, Proc. of SPIE Vol. 7709, 770903 · © 2010 SPIE · CCC code: 0277-786X/10/$18 · doi: 10.1117/12.855673



Focus

Conduct research and demonstrate information technology to span the gap from energy detection to knowledge creation; Applications include; crisis management , military situation assessment, intelligence, environmental monitoring and monitoring of complex systems.

Research Areas

Research areas include: humans as soft sensors, state estimation, pattern recognition, automated reasoning, human-system interaction, knowledge representation and hybrid cognition., dynamic resource allocation.

Facilities and Resources

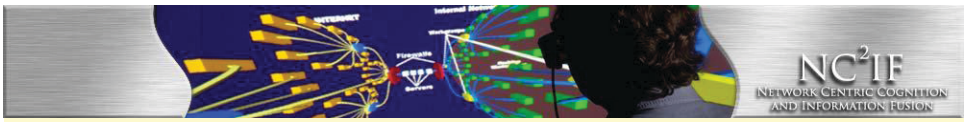
- ***Experimental test-beds –*** Living laboratory experiments and test beds to demonstrate and evaluate distributed cognition in real environments
- **Classified environment** - Access to classified computer networks and SCIFs,
- ***Education and training*** – Data fusion courses, seminars and tracks for information fusion

Experimental Capabilities
- 3-D Visualization
- Haptic interfaces
- Intelligent agent cyber advisors
- Sonification

We develop methods to transform energy and data into actionable knowledge to conserve the ultimate limited resource: human attention units

Faculty, Staff, and Students

- Dr. David L. Hall (Director)
- Col. Jacob Graham (Deputy)
- Ms. Rachana Agumanidi
- Mr. Guru Airy
- Dr. Stan Aungst
- Dr. Mark Ballora
- Mr. Derek Bartlett
- Mr. Jon Becker
- Mr. Yan Cao
- Ms. Xue Dong
- Ms. Julia Erdley
- Dr. Fred Fonseca
- Dr. Peter Forster
- Mr. Nick Giacobe
- Dr. Lee Giles
- Dr. Ed Glantz
- Mr. Justin Granger
- Dr. John Hogan
- Mr. Hemant Kumar
- Dr. James Llinas (UB)
- Dr. Michael McNeese
- Ms. Loretta More
- Dr. William McGill
- Mr. Eric McMillan
- Dr. Tracy Mullen
- Dr. Irene Petrick
- Dr. Mark Pfaff
- Mr. Kaustubh Misra
- Ms. Venkata Pisupati
- Mr. Jeff Rimland
- Mr. Dave Reber
- Mr. David Saab
- Mr. Don Shemanski
- Mr. Wade Schumaker
- Mr. Jung-Woo Sohn
- Mr. David Sudit
- Dr. Allen Sonsteby
- Mr. Jeff Vernon
- Dr. James Wang
- Dr. John Yen
- Ms. Michelle Young
- Dr. Luke Zhang

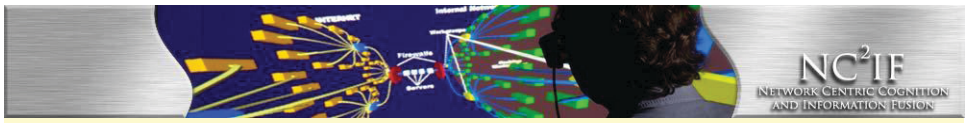


Origin of the JDL Data Fusion Model

- JDL Data Fusion Sub-Panel (and working group)
- Meeting in State College, PA in 1991
- Development of briefing for the Office of Naval Intelligence
- Functional model
  - 3-level model; processes, functions, algorithms
  - Improves communications across application domains
  - Not intended for implementation or taxometric Gospel

Joint Directors of Laboratories (JDL) Data Fusion Working Group:
- Ed Waltz
- Chee Chong,
- Frank White,
- Otto Kessler,
- David Hall,
- James Llinas
- Alan Steinberg

O. Kessler, K. Askin, N. Beck, J. Lynch, F. White, D. Hall & J. Llinas, Functional Description of the Data Fusion Process Office of Naval Technology Data Fusion Development Strategy Technical Report, Warminster, PA, Nov 1991



The DoD Legacy: Extensive Research Investments

- **JDL Process model**
- **Related process models**
  - Ensley's model, Salerno's model OODA loop
- **Taxonomy of Algorithms**
- **Lexicon(s)**
- **Engineering Guidelines**
  - Architecture Selection
  - Algorithm Selection
- **Evolving Tool-kits**
- **Extensive Legacy of technical papers, books**
- **Training Materials**
- **Test-beds**
- **Numerous prototypes**

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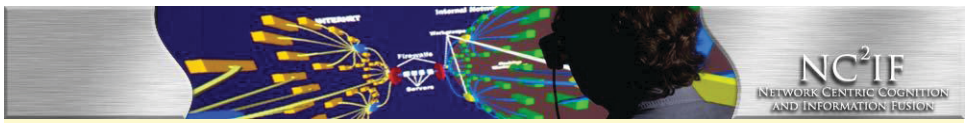

IT Trends that Affect Information Fusion

- New sensor types – ubiquitous sensing
- New human computer interfaces
- Explosion of data on the web
- Increasing bandwidths and connectivity
- Increasing computational power and *invisible computing*

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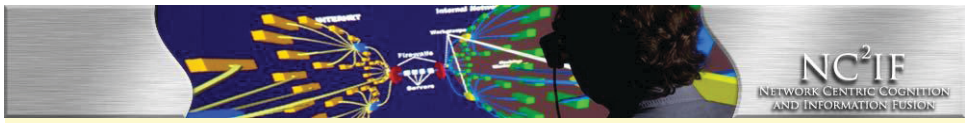


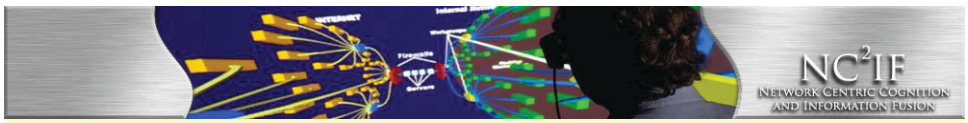
Web Infrastructure: What is Web 2.0 ?

- Term coined by Tim O'Reilly and Media Live International as part of brainstorming session about the future of the web in 2005
- Also may be called the Live Web or Living Web
- Refers to more interactive technologies that engage, facilitate and empower users
- Companies utilizing interactive technologies are the hot investments
- Companies are just starting to embrace these technologies for business value

Web 1.0		Web 2.0
DoubleClick	-->	Google AdSense
Ofoto	-->	Flickr
Akamai	-->	BitTorrent
mp3.com	-->	Napster
Britannica Online	-->	Wikipedia
personal websites	-->	blogging
domain name speculation	-->	search engine optimization
page views	-->	cost per click
screen scraping	-->	web services
publishing	-->	participation
content management systems	-->	wikis
directories (taxonomy)	-->	tagging ("folksonomy")
stickiness	-->	syndication

7

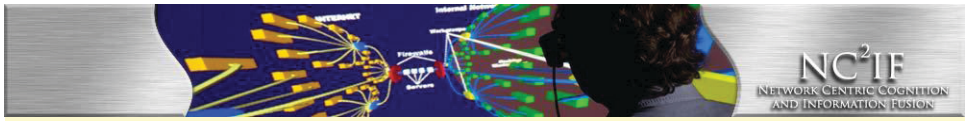
Source: www.oreilly.com, "What is web 2.0: Design Patterns and Business Models for the next Generation of Software", 9/30/2005



The New Digital Native Generation

- Different sense of privacy
- A sense of commitment to their digital community
- Different modes of accessing expertise – reliance on collaborative expertise
- Different time scales of interaction
- Multi-tasking
- Different expectations regarding information technology

The new generation of digital natives treats the cyber infrastructure significantly different than the digital immigrants



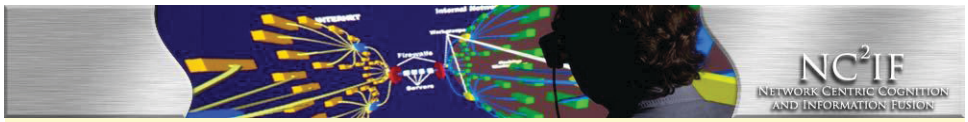
Our Vision of Empowered Information Users

Real-world knowledge

Textual data exemplars

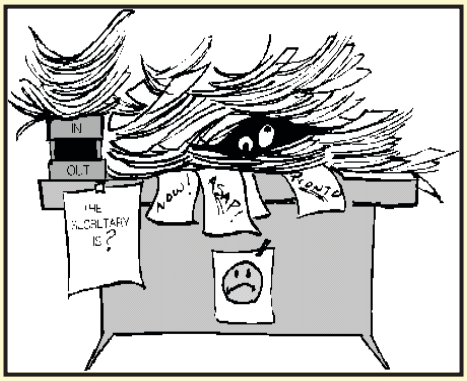
Correlated, conditioned data

An instrumented, networked world ⟷ **The knowledge empowered human**

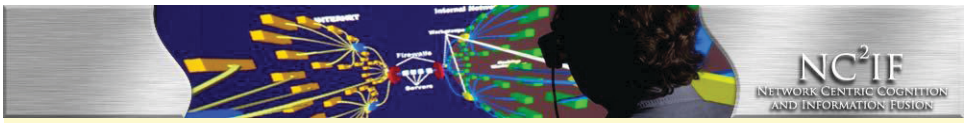


The Unfortunate Reality

- Most problems are complex and *information rich* but *model poor*
- Required reaction times have decreased from days to minutes
- Fewer analysts are available to work more data and more problems
- Anywhere, anytime threats with no a priori doctrine
- Information gathering equity by 3rd world and terrorist opponents
  - Asymmetric information warfare
  - Improvised Information Devices (IIDs)



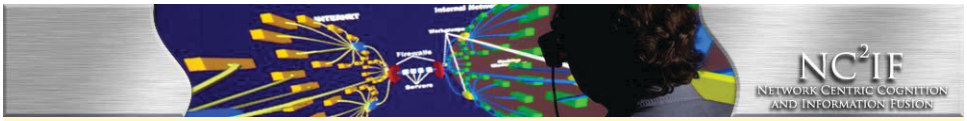
The ultimate limiting resource is human attention units (HAUs)



Example of IT Asymmetric Warfare: *Mumbai Attacks November 2007*

- Handheld GPS
- Google Earth satellite imagery
- Satellite phones
- Mobile phones
- VoIP telephony
  - Difficult to tap, trace
- Live television coverage analyzed offshore
  - Findings relayed to attackers

Rapid evolution of COTS IT and creative utilization by digital natives threatens U. S. C⁴ISR advantage



Traditional and Evolving Role of Information Fusion

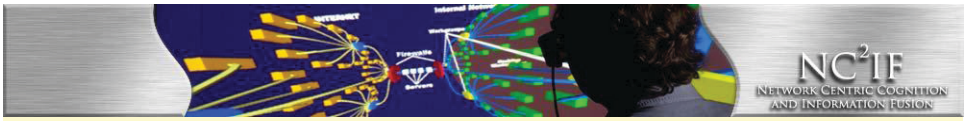
Traditional Roles and Focus

- Focus on physical targets
- Reliance on "hard" sensors
- Data driven approach
- Analyst viewed as "passive" user of fusion products
- Relative control of information resources

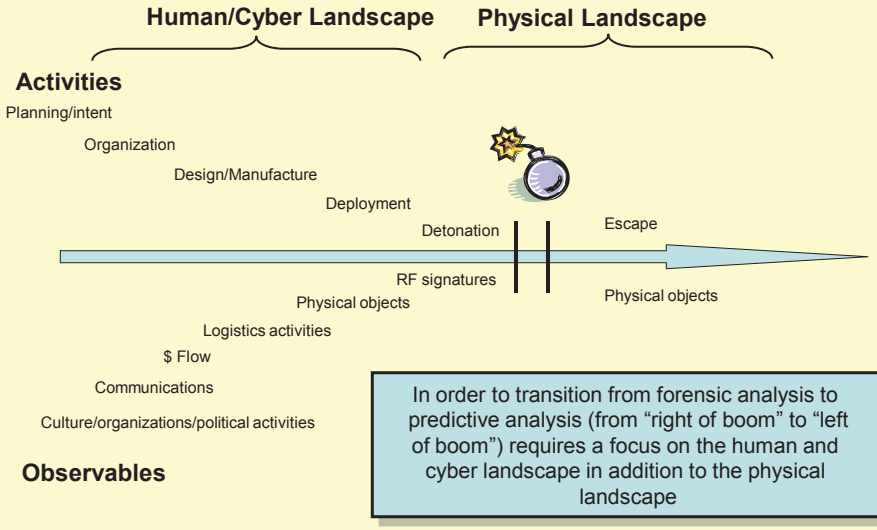
Evolving Roles and Focus

- Extension to non- physical targets
- Use of "soft" sensors and I-space
- Hypothesis driven approach
- Analyst viewed as active user of fusion products
- Uncontrolled "ad hoc" information resources

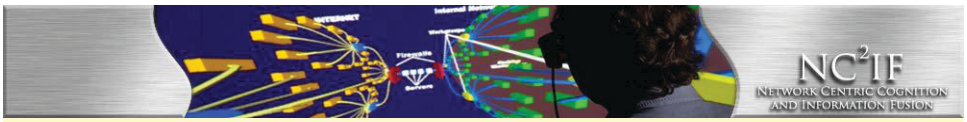
- **Human landscape focus** – Focus on human activities and interactions versus the physical landscape
- **Every human a sensor** - Ad hoc community of observers
- **Hybrid human/machine cognition –** Explicit use of human pattern recognition & semantic talents to augment automation
- **Every human an analyst** - Ad hoc community of analysts for improved multi-perspective analysis



Getting to Left of Boom



In order to transition from forensic analysis to predictive analysis (from "right of boom" to "left of boom") requires a focus on the human and cyber landscape in addition to the physical landscape



Cultural Awareness: Understanding, Sensitivity & Appreciation **

- **History**
- **Values**
- **Experiences**
- **Behaviors**
- **Interactions**
- **Lifestyles of groups**
  - **Race**
  - **Ethnicity**
  - **Gender**
  - **Sexual Orientation**
  - **Religious affiliation**
  - **Socio-economic status**
  - **Mental/physical abilities**

** Colorado State University Research Center

"Culture is the human terrain of warfare. Human terrain is the key terrain." **MG(Ret) Geoffrey Lambert**

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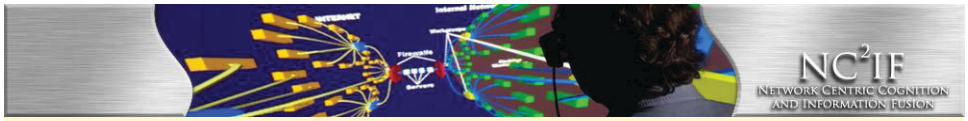

Implications and Assertions

- We must observe and understand the human terrain
  - New threats require understanding the human terrain as well as the physical terrain
- We will be (and are being) overwhelmed by a data tsunami
  - Ubiquitous connectivity
  - Overwhelming amounts of persistent data
  - Emerging "every soldier a sensor" concept (and corollary – every civilian a sensor)
- We must cope with hybrid "hard/soft" sensors
  - Sensors carried/worn by soldiers/civilians
  - Sensors that monitor the condition of people (e.g., using the human body as a sensor for complex chemical/biological phenomena and monitoring the body's responses)
  - Self-reporting via soldier as "continuous commentator"
  - Emergent social phenomena – mining soldiers chat & blogs for emerging insights and unconscious insights
- We must consider new roles for humans in fusion systems

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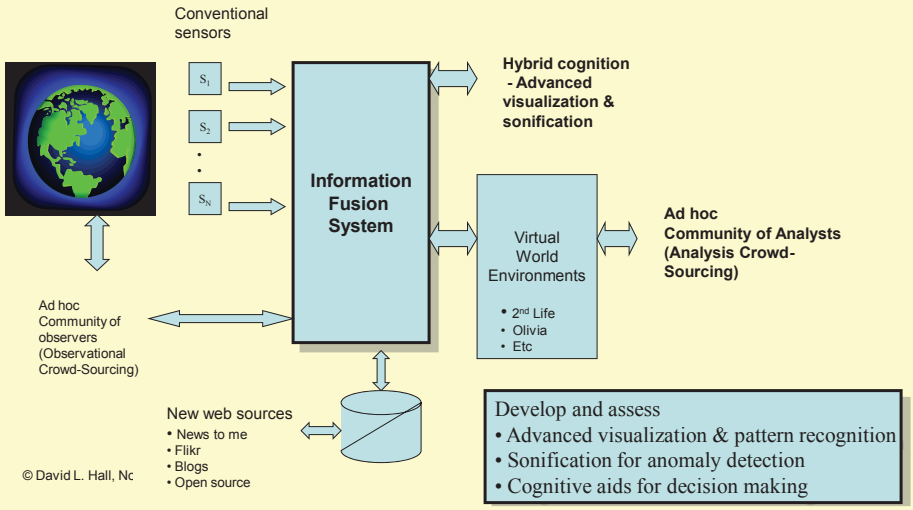
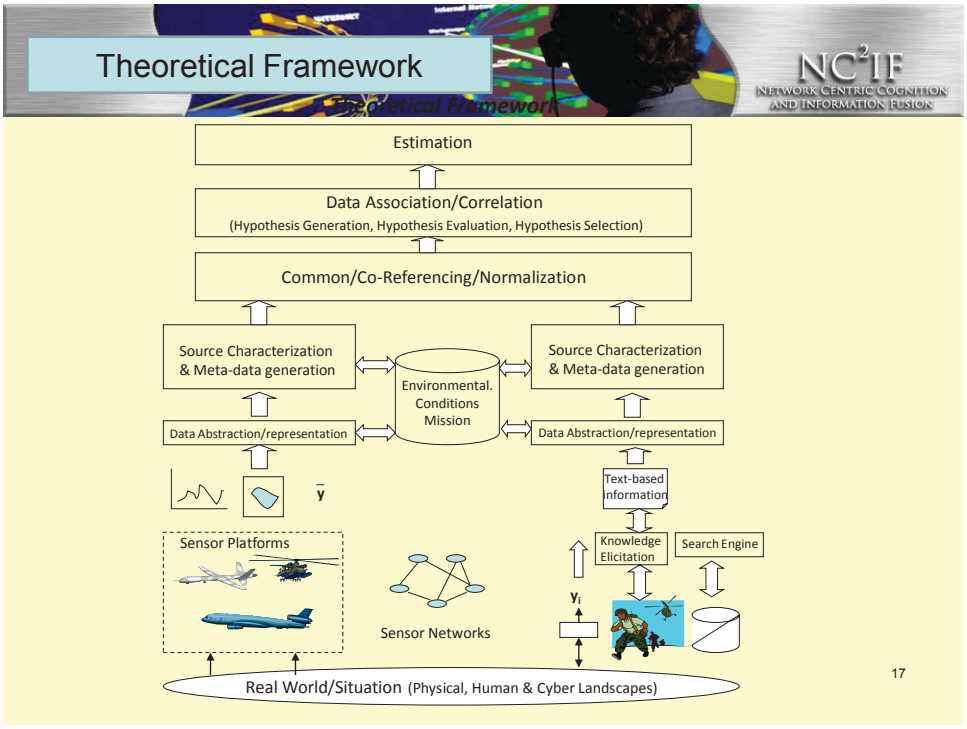
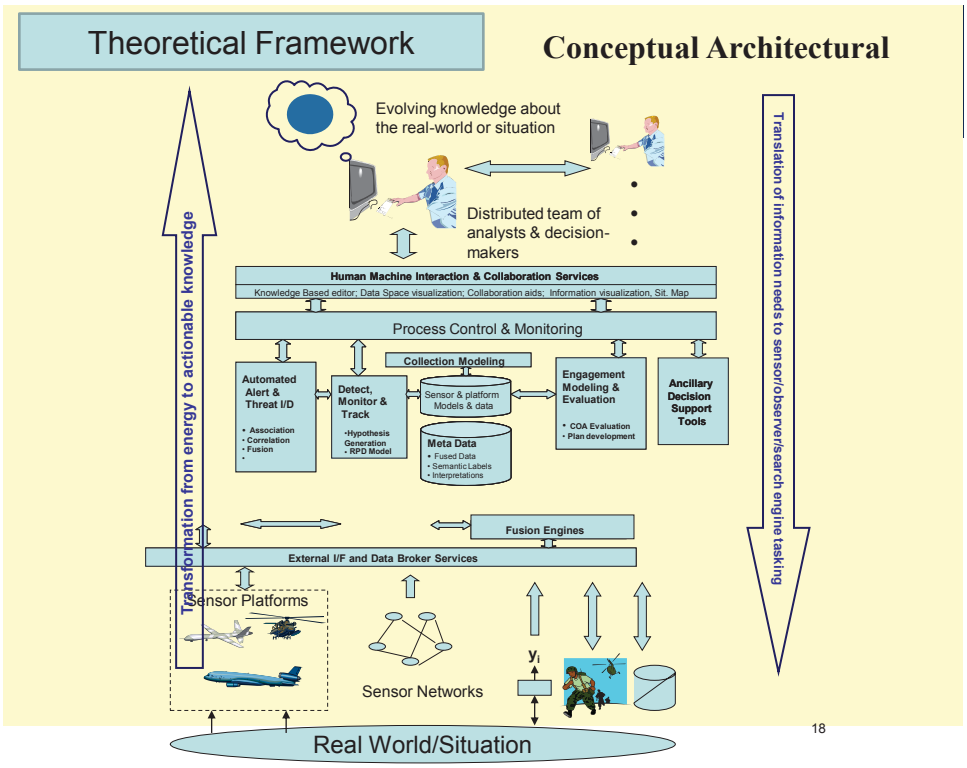
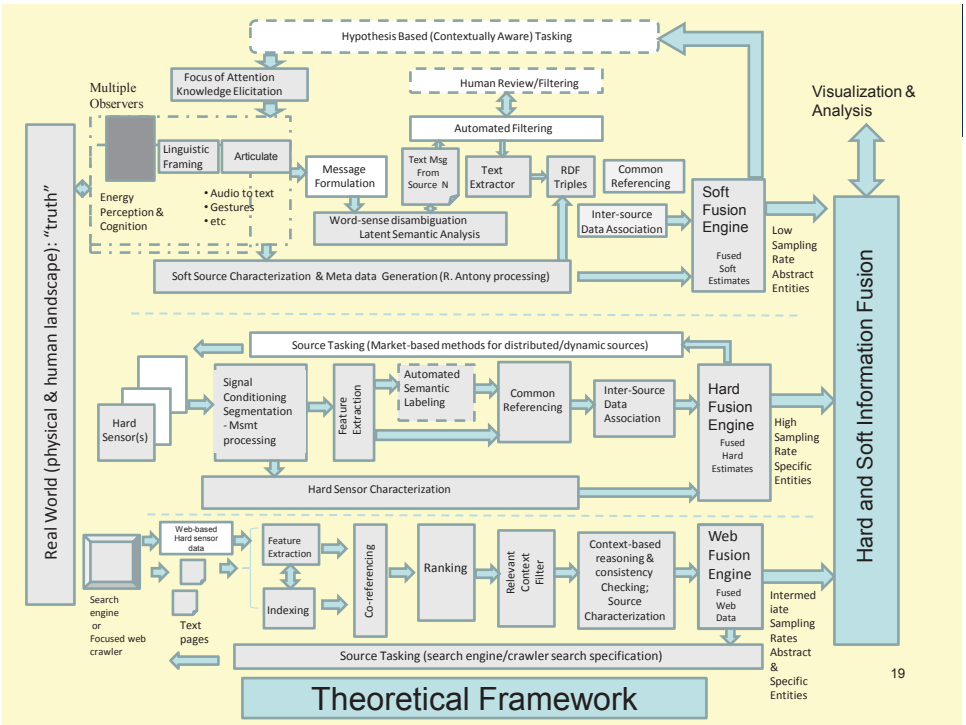
A Conceptual Framework: Human Centered Information Fusion




Theoretical Framework
NC²IF
Network Centric Cognition and Information Fusion
Theoretical Framework
Estimation
Data Association/Correlation
(Hypothesis Generation, Hypothesis Evaluation, Hypothesis Selection)
Common/Co-Referencing/Normalization
Source Characterization & Meta-data generation
Environmental. Conditions Mission
Source Characterization & Meta-data generation
Data Abstraction/representation
Data Abstraction/representation
Text-based information
Knowledge Elicitation
Search Engine
Sensor Platforms
Sensor Networks
Real World/Situation (Physical, Human & Cyber Landscapes)
17


Theoretical Framework
Conceptual Architectural
Evolving knowledge about the real-world or situation
Distributed team of analysts & decision-makers
Human Machine Interaction & Collaboration Services
Knowledge Based editor; Data Space visualization; Collaboration aids; Information visualization, Sit. Map
Process Control & Monitoring
Collection Modeling
Automated Alert & Threat I/D
Detect, Monitor & Track
Sensor & platform Models & data
Meta Data
Engagement Modeling & Evaluation
Ancillary Decision Support Tools
Fusion Engines
External I/F and Data Broker Services
Sensor Platforms
Sensor Networks
Real World/Situation
Transformation from energy to actionable knowledge
Translation of information needs to sensor/observer/search engine tasking
18



Video Image Processing Demonstration

Initial algorithms and demonstrations: Video Image Processing

- Notional video surveillance
- Real-time processing of video "snapshots"
- Automated entity recognition
- MATLAB-based image processing
- Training via still image database

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Participatory Sensing Demonstration

Initial algorithms and demonstrations: Text processing

- Human observers act as “soft” sensors
- Observations reported via iPhone application
- Semi-automated text extraction
- Intelligent agents used for information monitoring & knowledge elicitation

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Public Web Data Analysis Demonstration

Initial algorithms and demonstrations: Monitoring web traffic

- Monitoring of open source twitter traffic
- Keyword-based querying within specified area of interest
- Intelligent agent based traffic monitoring and filtering

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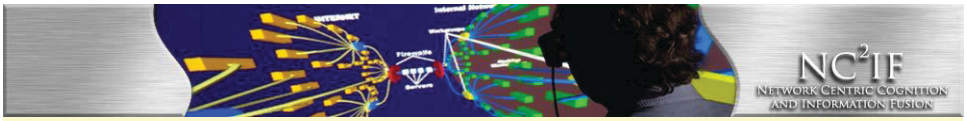
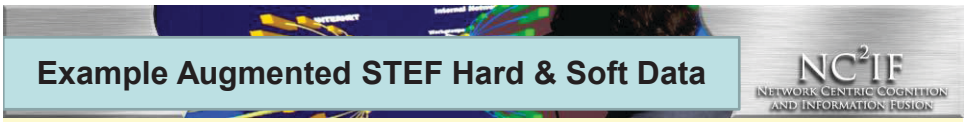


Evolving Data Sets

- **Hasten Data Set**
  - Data set of hard and soft (after action reports) collected on DARPA sponsored blue team/red team Counter Insurgency (COIN) exercise
- **STEF Data Set**
  - Army Research Laboratory *Soft Target Exploitation and Fusion* (STEF) program
  - COIN inspired scenario in IRAQ
  - 100 message set over 4 month period related to tactical operation
- **Enhanced STEF Data Set**
  - Enhanced scenario to include additional I-space information, background information, synthetic associated hard data
- **PSU COIN Analogy Human in the Loop Data**
  - COIN inspired Penn State campus data collection with hard and soft data



Example Augmented STEF Hard & Soft Data

Augmented Simulated Predator Photo-interpretation

- Target: Dhubat Complex 5
- 3/17/09
- On Target time 0347Z
- At 0358Z white sedan pulled up to the east side of building 5F
- At 0400Z one FAM exited white sedan and entered building 5F. White sedan then pulled out and drove north.
- At 0632Z two FAMs approached on foot from the south and entered building 5F
- At 0731Z a gray van approached from the north and pulled into parking lot south of building 5F
- At 0735Z one FAM exited the front passenger door and entered building 5F. Van then exited parking lot and proceed north on road
- At 1300Z one FAM exited building 5F and walked south
- At 1340Z one FAM exited building 5F and walked south
- At 1829Z a gray van approached from the north and pulled into parking lot south of building 5F
- At 1830Z one FAM exited building 5F and entered gray van. Gray van exited parking lot and proceeded north on road.
- Off TGT at 1952Z
-
- 3/19/07
- On Tgt time 0405Z
- No activity observed
- Off TGT at 1650Z
-
- Iraq time – Zulu plus three
- FAM – Fighting age male.
-

Original STEF Message Report

- STEF DATA:
- 54. 03/17/07 - Surveillance of house #23 on Dhubat Street found that Sufian Mashhadan entered at 0700. Two unknown males, approximately 18 to 20 years old, visited the house at 0932. Another male, identified as Khalid Sattar, arrived at 1035. One of the unidentified men left at 1600, the other at 1640. Sattar left at 2130.
-
- 58. 03/19/07 - Nobody seen entering or leaving house #23 on Dhubat street that is under
- surveillance.

Simulated Predator Observation

Human-in-the-Loop Experiment Scenario

Purpose
Establish a “baseline” or “ground truth” to compare data collected from hard sensor data (video and GPS location) and soft sensor data (human observation reports via handheld devices). Conduct further experiments in a phased approach using more complex scenarios and data sources.

Example Scenario:

- Target begins at start location and is identified as wearing an orange backpack.
- Target heads west and interacts with another subject (receives an envelope at location point 1).
- Target heads in a south-easterly direction and interacts with subject (handshake) at location point 2.
- Target continues north back to starting location.

Data Feeds:

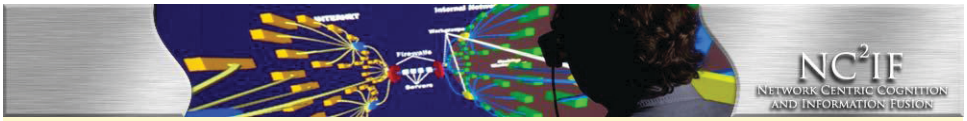
- Multiple remote observer reports (i.e. Twitter)
- Fixed and mobile video
- Acoustic Sensors

Technology Transition via Fusion Exploitation Framework

Fusion Exploitation Framework (FEF)

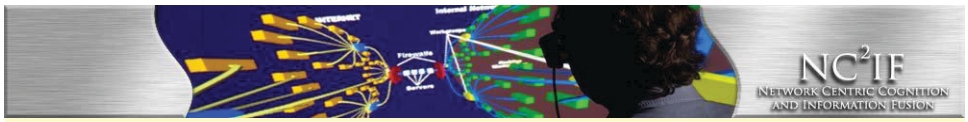
- Cross-platform, open framework that permits fusion application developers to focus on the creation of modular data fusion algorithms
- FEF is designed and implemented such that new algorithms can interact with any other running algorithms, independent of contributing vendors.

Source: Potomac Fusion, Inc



Examples of On-Going Research

- **Characterization of human reports and observers**
  - Mathematical models for fuzzy observations
  - Models of 2nd order uncertainty
- **Computer assisted knowledge elicitation**
  - Analog to hard sensor "look angle" calculations
  - Guided information collection/uncertainty representation
- **Dynamic Resource Allocation**
  - Market-based hard/soft resource allocation
- **Advanced visualization and sonification**
  - Improved situational awareness for physical, human and cyber landscapes
- **Exploration of military/NGO interactions**
- **Continued development of Extreme Events Laboratory Infrastructure**
- **Advanced search engines and creation of data spam filters**
- **Virtual world environments for dynamic community of analysts**
- **Fusion of hard and soft data**



PSU – MITRE Project
Bridging the Decision-Space to Situation-Space Divide

Objectives

- Investigate decision aids to enhance support of emergency response decision making
- Let emergency responders visualize more futures and save more lives through Robust Decision Making (RDM)

Research Participants

The MITRE Corporation: *Dr. Gary L. Klein, Dr. Jill Drury, Dr. Jennifer Mathieu, Nathan Rackliffe*
Penn State University: *Dr. David Hall, Loretta More, Robert Hooper*
Indiana University Indianapolis: *Dr. Mark Pfaff*

NeoCITIES RDM Analysis

Project Plan

- Modeling analysis (Phases 1 and 2): completed
  - Develop guidelines for the tradeoff space between accuracy, precision, and completeness of models to generate RDM displays
- Human experimentation (Phases 3 and 4):
  - Develop two RDM visualizations that enable emergency responders to understand the robustness of any given course of action (COA)
  - Perform human-in-the-loop testing for each visualization at PSU to assess subjects' decision-making performance

Joint Publications

1. Data Visualizations for Dynamic Decision Support – IUI 2009
2. A Principled Method of Scenario Design for Testing Emergency Response Decision-Making – ISCRAM 2009
3. Modeling as an Aid to Robust Tactical Decision-Making – 14th ICCRTS
4. Dynamic Decision Support for Emergency Responders - IEEE HST 2009

Improving Operational Effectiveness through Improved Situational Awareness of Human Terrain

NC²IF

Situational Awareness of Human Terrain

Technology / Product / Key Deliverables

- **Situational Awareness tools for Mil Operations**
- **Framework and modeling of Human Terrain**
- **Operational/Tactical Scenario to demonstrate HT-SA model**
- **Training materials for Human Terrain modeling**

Benefits

- **Improved understanding of Human/Social dimension**
- **Improve our military unit effectiveness across domains**
- **Improve the image of our nation globally**

Key Participants

- **Sponsor (s): DDR&E/Rapid Reaction Technology Office (RRTO)**
- **Other Gov't Contributors: Joint IED Defeat Organization, Army Research Lab, Office of Naval Research**
- **Industry: MITRE, Lockheed Martin**

Summary of Results

- Developed a theoretical framework for hard and soft information fusion
- Established an Extreme Events Laboratory in IST Building
- Conducted initial human in the loop experiments in participatory sensing
- Explored exploitation of 3G/4G technologies
- Established collaboration with multiple agencies
- Developed new educational course materials

Technical POCs: David Hall dhall@ist.psu.edu, 814-867-2154
Jake Graham jlg34@psu.edu, 814-863-6322
PM PoC: Tom Goodall, tdg10@only.arl.psu.edu, 814-574-1767

Recent Publications

1. D. Hall and J. Jordan, *Human-Centered Information Fusion*, Artech House (in press)
2. D. Hall and J. Graham, chapter 8 in *Human-Centered Information Fusion*, by D. Hall and J. Jordan, Artech House (in press)
3. D. Saab and F. Fonseca, *Participatory Sensing: A Review of the Literature and State of the Art Practices,* Technical Report for the Penn State University Center for Network Centric Cognition and Information Fusion (NC2IF), November 11, 2009 (78 pages)
4. A. Tapia, C. Maitland, H. Robinson, *Human Sensors and Awareness: Addressing NGO Information Requirements*, Technical Report for the Penn State University Center for Network Centric Cognition and Information Fusion (NC2IF), Sept, 2009 (58 pages)
5. M. Young, *Human Terrain: A Literature Review*, Technical Report for the Penn State University Center for Network Centric Cognition and Information Fusion (NC2IF), Oct, 2009 (17 pages)
6. A. Levy and M. Young, *Assessment of the State of the Art on Human Terrain Representation*, Technical Report for the Penn State University Center for Network Centric Cognition and Information Fusion (NC2IF), Sept, 2009 (18 pages)

- Established framework for human-centered information fusion
- Experimental and implementation environment
- Multiple on-going research projects
  - Theoretical foundations
  - Demonstrations and algorithm implementation
  - Creation of calibrated data sets
  - Technology transition via FEF

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