APTIMA
HUMAN-CENTERED
ENGINEERING

Identifying the Enemy – Part II: Algorithms versus Human Analysts

The Command & Control Research & Technology Symposium, Newport, RI

19 June 2007

Elliot E. Entin
Rebecca Grier
Tyrone Jefferson
Georgiy Levchuk

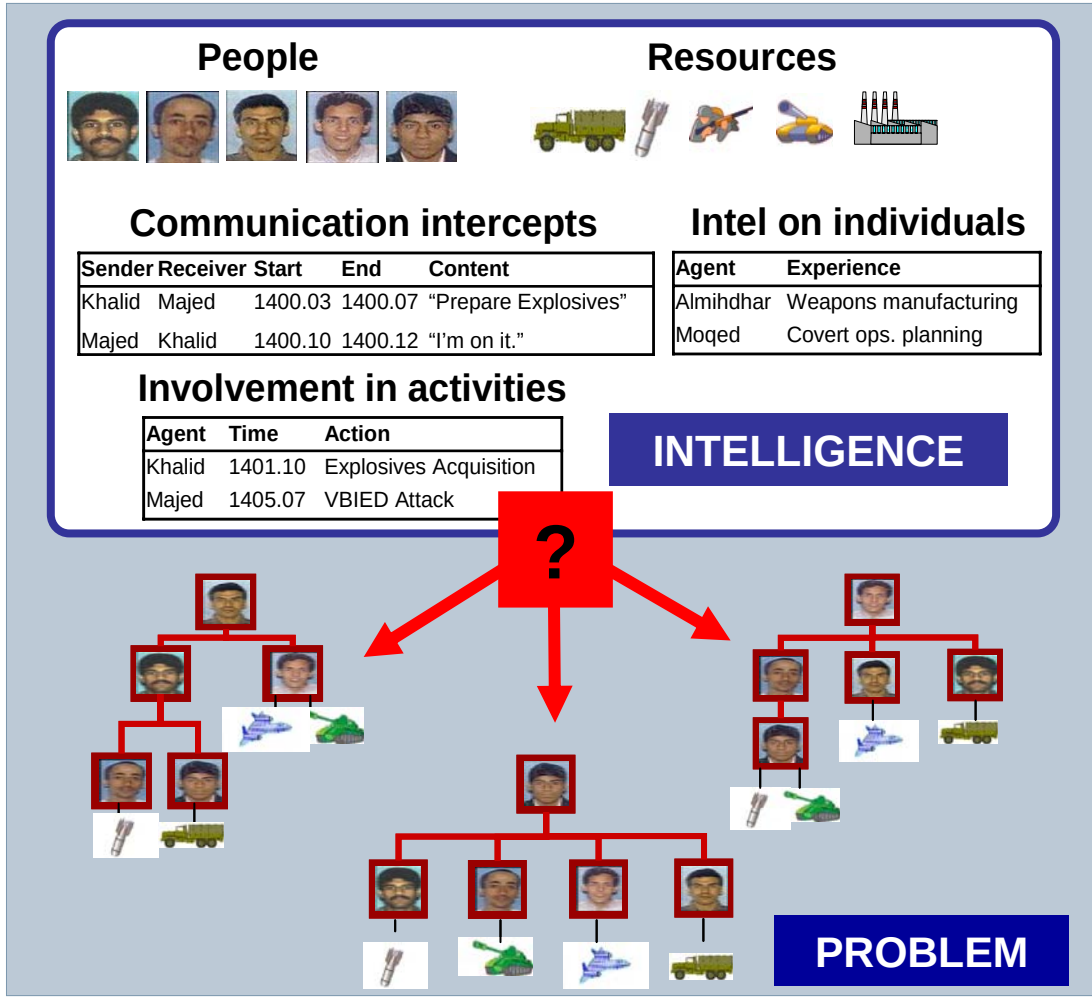
DARPA NPS

NetSTAR Problem Formalization

- Cannot effectively predict enemy's COAs w/o knowing **enemy C2 organization**
- Cannot develop effective enemy HVTs & counteractions w/o knowing **enemy C2 organization**
- Might entail unintended consequences if the action is taken w/o full realization of the C2 structure and roles of individuals

How can we recognize the **enemy C3I organization** given uncertain observations

- *Actors*
- *Resources*
- *Communication intercepts*
- *Involvement in activities*
- *Intel on individual actors & resources*



APTIMA
HUMAN-CENTERED ENGINEERING

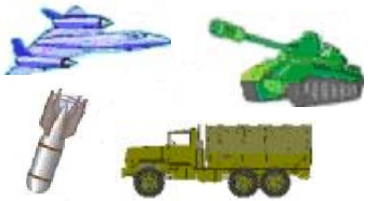
Main Premise:

Organizational Interactions Form Structural Patterns

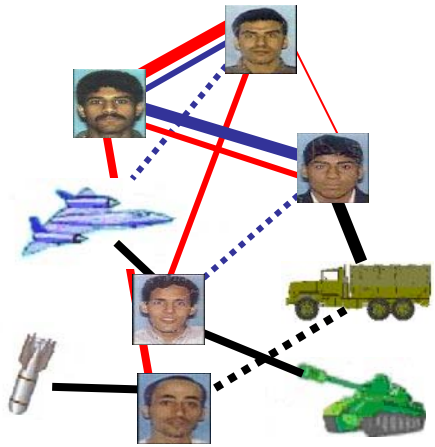
Tracked Actors

Enemy commanders

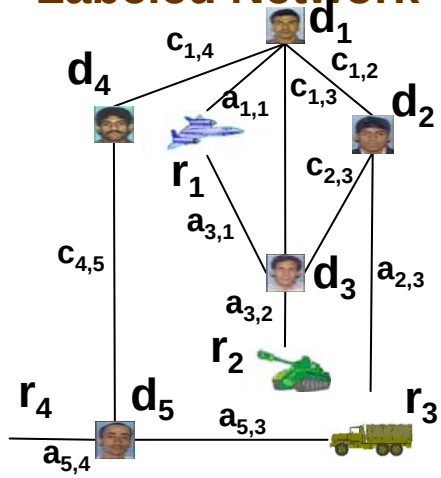
Units/Assets



Observed Interactions



Labeled Network



Labels

- Vector of values for quantitatively representing multiple relationship types
- Value weighs the relationship

Node labels

- **Source:** area of responsibility, performed functions/tasks, expertise
- **Example:** sniper ops; sales of weapons; money laundering

Link labels

- **Source:** types of messages
- **Example:** transfer of information; action request; synchronization; etc.

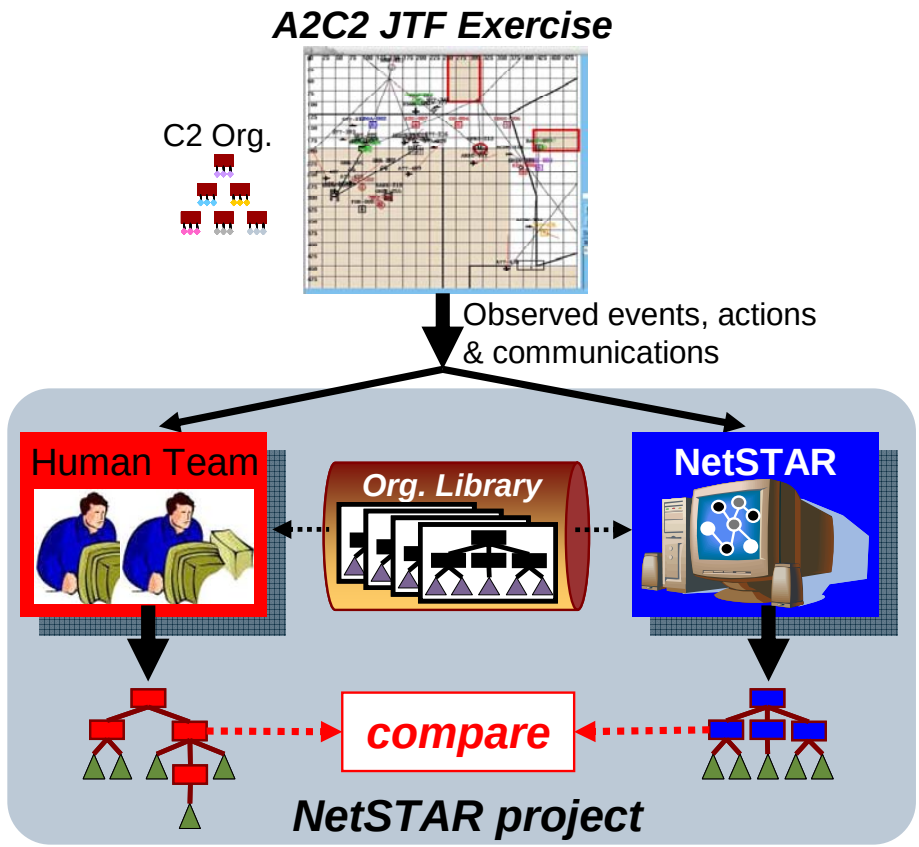
Hypotheses Networks

- Link labels correspond to expected volume of messages

DARPA NPS

NetSTAR Validation Design

- Reuse readily available data from human-in-loop A2C2 Experiments
  - JTF operations; 42 data samples
  - Communications manually coded
  - Events logged in
- Complexity
  - Number of commanders = 6
  - Number of assets = 137
  - Number of events, comms = 1000-4000
- Data uncertainty model based on probability of miss, deception, & error
- Identification of nodes: **actor-node mapping**
- Identification of resource allocation: **control structure**



- Compare results of detecting adversarial organizations as produced by human **2-person test team** in 1 hour vs **algorithm**
- Calculate the impact of information uncertainty on prediction accuracy

NetSTAR: Experimental Design

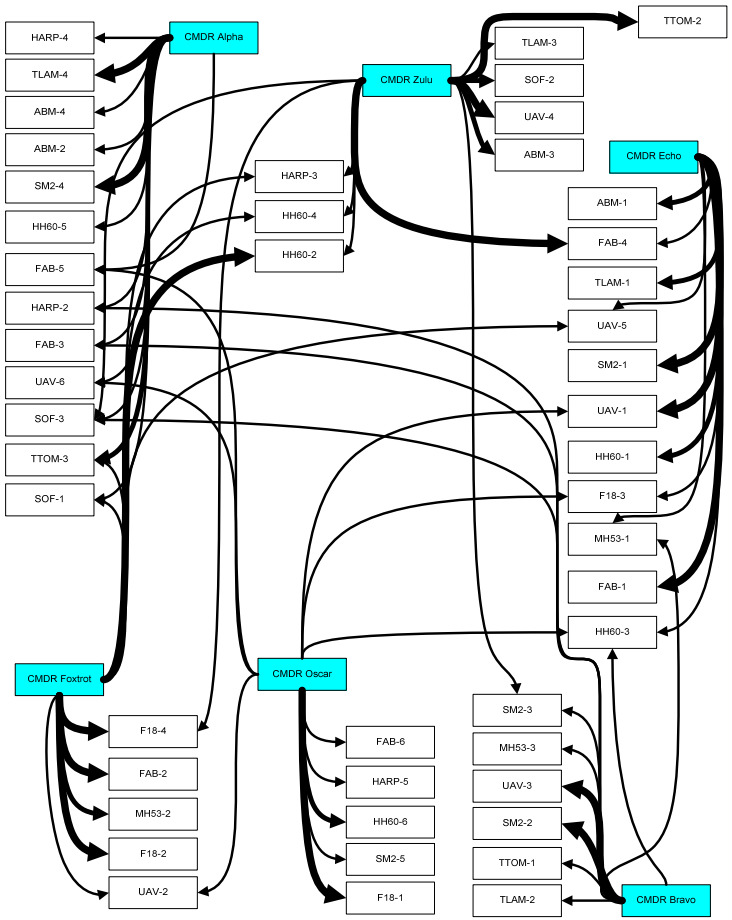
- Two independent variables: organizational type and amount of "data fogging" (noise or error)
  - Three organizational types: Functional, Divisional, and Intermediate structures
  - Three levels of data fogging (Low - 10%, Medium - 30%, Large - 50%)
- The five organizational structures-data fogging conditions tested were:
  - Functional 30%
  - Divisional 30%
  - Intermediate 10%, 30%, 50%
  - Incomplete design

Experimental Design & Counter-balancing

- Each of the nine 2-person teams saw four within-subjects trials

Team 1	*Team 2*	*Team 3*	*Team 4*	*Team 5*	*Team 6*	*Team 7*	*Team 8*	*Team 9*
D-30%	**F-30%**	**D-30%**	**F-30%**	**D-30%**	**F-30%**	**D-30%**	**F-30%**	**H-30%**
H-10%	**D-30%**	**H-10%**	**H-50%**	**F-30%**	**H-30%**	**F-30%**	**H-30%**	**H-50%**
H-50%	**H-30%**	**F-30%**	**D-30%**	**H-50%**	**H-10%**	**H-10%**	**D-30%**	**F-30%**
F-30%	**H-10%**	**H-50%**	**H-10%**	**H-30%**	**D-30%**	**H-30%**	**H-50%**	**D-30%**

NetSTAR Experimental Procedure



Input Example: Network of Intercepted Control Messages from CMDRs to units/assets

(Data Sample: Divisional Org)

Procedure

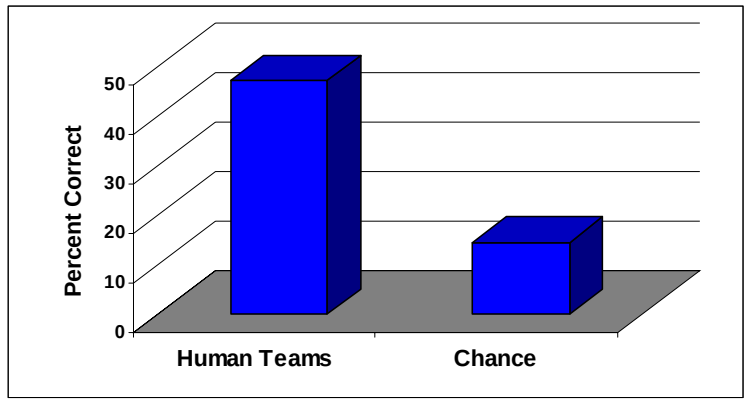
- Teams were trained with the data from study
- Teams were given **one stimulus data set** and tasked to **matching it to 1 of 7 hypothesis** C2 structures
- Stimulus data set was **noisy** (contained errors)
- 7 hypothesis C2 structures were error free
- 7 hypothesis C2 structures included 1 functional, 1 divisional, and 5 intermediate or hybrid structures
- Description of each organizational structure was presented in 9 spreadsheets & 9 diagrams
- At the end of each trial, teams developed two products
  - Surveys measuring:
    - Self-reported workload,
    - Selection confidence,
    - Perceived Fogging Level
    - and Perceived Complexity
  - **Mapping between Commanders, Leaders, & Assets**

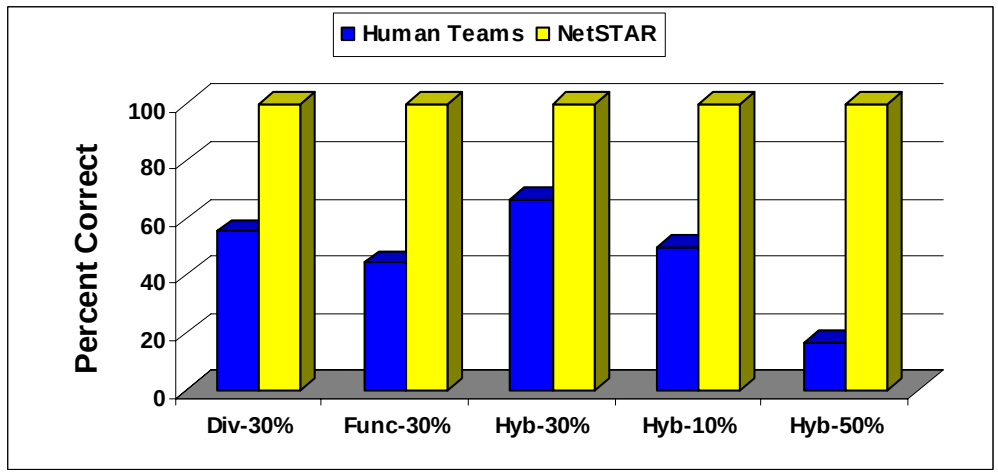
		Observed					
	Commanders Mapping	CMDR Alpha	CMDR Bravo	CMDR Charlie	CMDR Delta	CMDR Echo	CMDR Foxtrot
Hypotheses	Green	x					
	Blue			x			
	Purple						x
	Red		x				
	Orange				x		
	Brown					x	

Output Example: Mapping between Observed and Hypothesis CMDRs

Identification of Organizational Structure

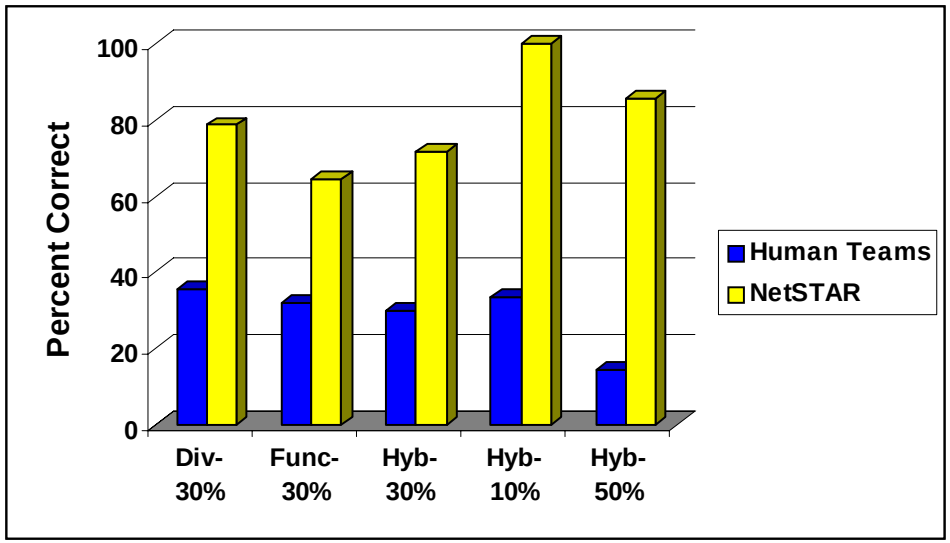
- Human teams identified organizational structure correctly in 17 of 36 trials or 47.2% of the time
  - If just chance, only 14.5% expected, human teams performed 230% better than chance
  - NetSTAR was perfect – 100% correct (110% better than human teams, $p < .001$)
  - Holding fogging level constant (30%), NetSTAR did significantly better for Divisional & Functional (ps < .05), but not Hybrid ($p = .2$)
  - Human performance worst when fogging was highest





Mapping of Commander & Combatant Platform Owners

- There were 14 nodes to match: 6 commander and 8 combatant platform owners
  - NetSTAR significantly out performed the human teams for every organizational structure (all ps < .001)
  - NetSTAR appeared to affected by organizational type



Conclusions

- The NetSTAR algorithm significantly outperformed the human analyst teams
  - identifying organizations
  - mapping commander and combatant platforms owners
- NetSTAR algorithm was unaffected by organizational type or amount of fogging when performing the identification task
  - This was not true for human teams
  - The higher the fogging (noise) the poor the performance
  - Functional organizations more difficult to identify than other organizations
- NetSTAR algorithm was affected by organizational type when performing commander and combatant platforms owner mapping
  - Human team mapping performance was weak but not affected by organizational type