

Operationalizing and Improving C2 Agility: Lessons from Experimentation

David S. Alberts
dalberts@ida.org

Marco Manso
marco@marcomanso.com

Agenda

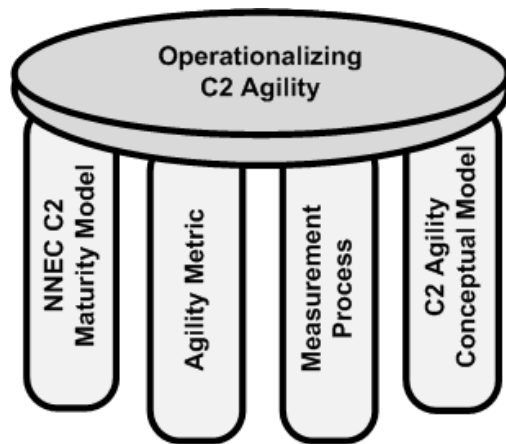
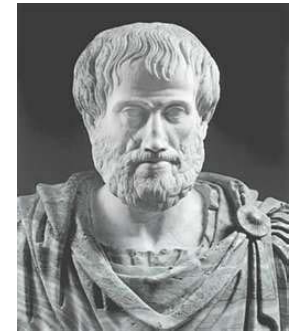
- Paper's Objectives
- From Theory to Practice: Cornerstones
- C2 Agility Experiments
- Results of Experiments
- Conclusions

Objectives

- Identify what it takes to “Operationalize C2 Agility”
- Determine if we are ready to improve the practice
- Provide a “proof of concept” by designing and conducting experiments
- Identify lessons learned from experiments regarding improving Agility C2

Operationalizing C2Agility

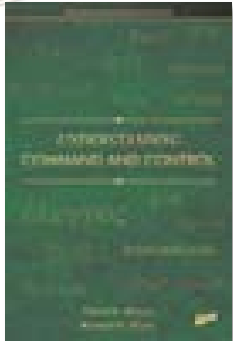
- Operationalize = move from a concept to a theory to a practice”
- “Excellence is not an act; but a habit” *Aristotle*
- Foundation to build practice upon



- Theory
- Metrics
- Measurement
- Milestones

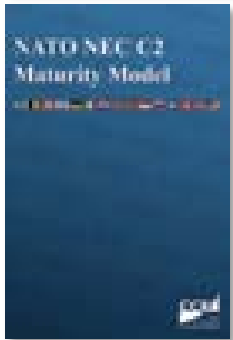
Operationalizing C2 Agility makes C2 Agility “a habit”

Theory: Conceptual Foundation



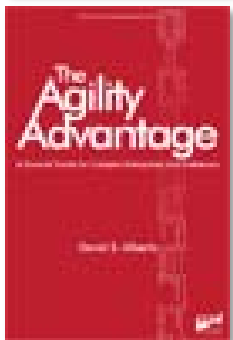
- C2 Approach Space
- C2 Conceptual Reference Model

Reference: Understanding Command and Control (2006)



- NATO NEC C2 Maturity Model (N2C2M2)
- C2 Maturity Levels

Reference: NATO NEC C2 Maturity Model (2010)



- Agile C2
- Agility Metric and Measurement Process

Reference: The Agility Advantage (2011)

What is Agility?

Agility is the capability
to successfully effect, cope with and/or exploit
changes in circumstances

What is Agility?

Agility is the capability
to successfully effect, cope with and/or exploit
changes in circumstances

- the concept of Agility does not apply to a stable situation
- external changes (e.g. regime change, permissive to hostile)
- changes to self (e.g. a new coalition partner, loss of capability)

What is Agility?

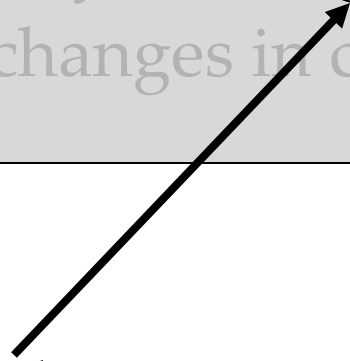
Agility is the capability
to **successfully** effect, cope with and/or exploit
changes in circumstances

within acceptable bounds of performance
(e.g. effectiveness, efficiency, risk)

What is Agility?

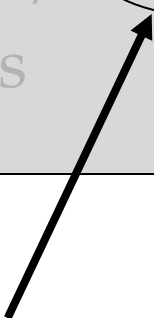
Agility is the capability
to successfully effect, **cope** with and/or exploit
changes in circumstances

respond to an event that
would otherwise have
adverse consequences



What is Agility?

Agility is the capability
to successfully effect, cope with and/or **exploit**
changes in circumstances



take advantage of an
opportunity to improve
effectiveness and/or efficiency
or reduce risk

What is Agility?

take actions to effect change or to prevent changes that might otherwise occur



Agility is the capability
to successfully **effect**, cope with and/or exploit
changes in circumstances

Components of Agility

- Responsiveness
- Versatility (previously referred as robustness)
- Flexibility
- Resilience
- Adaptiveness
- Innovativeness

The contributions of these components to agility are not additive

C2 Agility

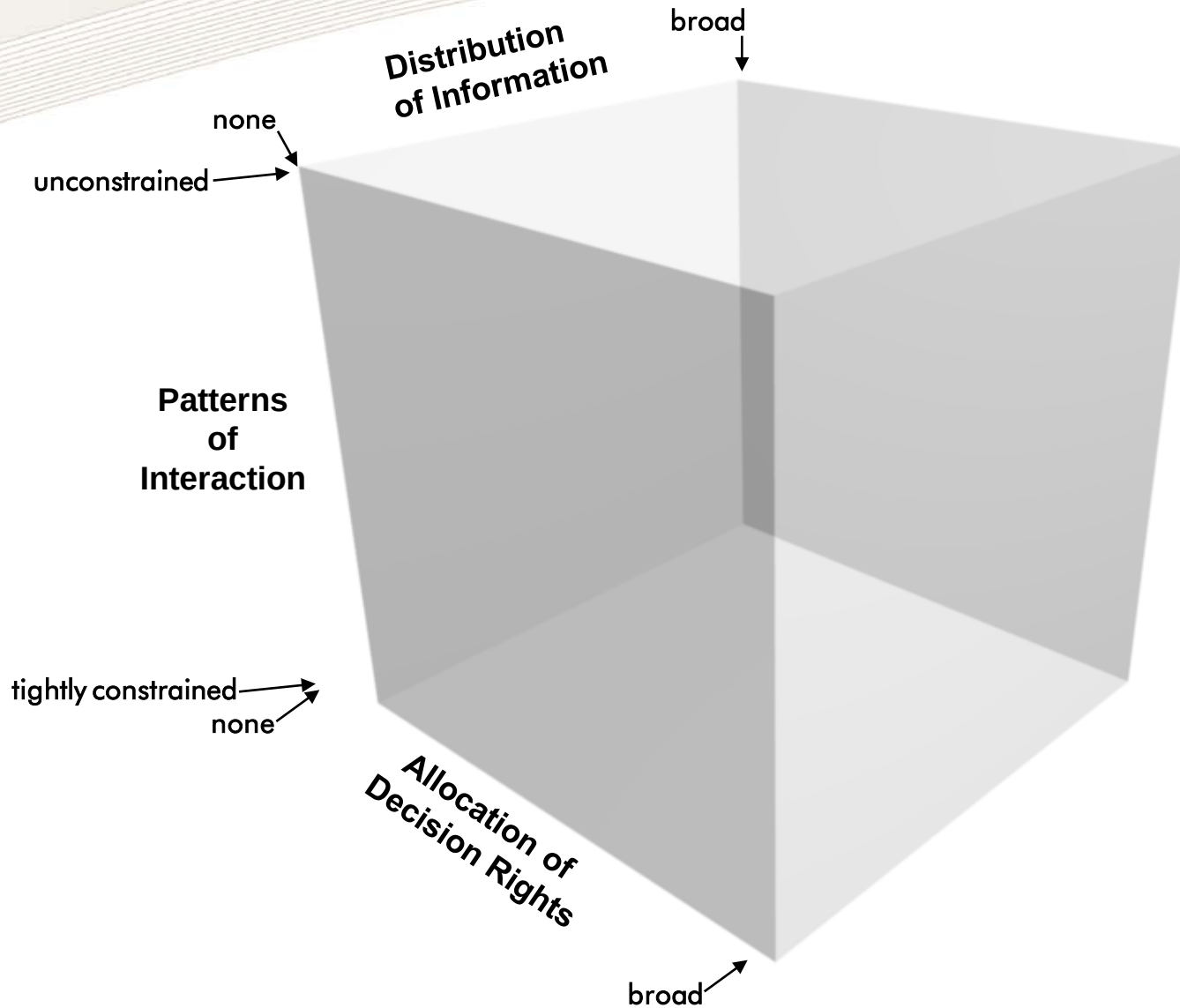
- There are many ways (i.e., approaches) to accomplish the functions associated with Command and Control
- No single approach to C2 (i.e., C2 approach) fits all missions or situations whether for a single entity or a collection of independent entities (a collective)
- The most appropriate approach will be a function of the endeavor and the prevailing circumstances
- Therefore, Entities (and Collectives) will need to be able to employ more than one approach

C2 Agility is the ability to appropriately move around in the C2 Approach Space in response to changing missions and circumstances

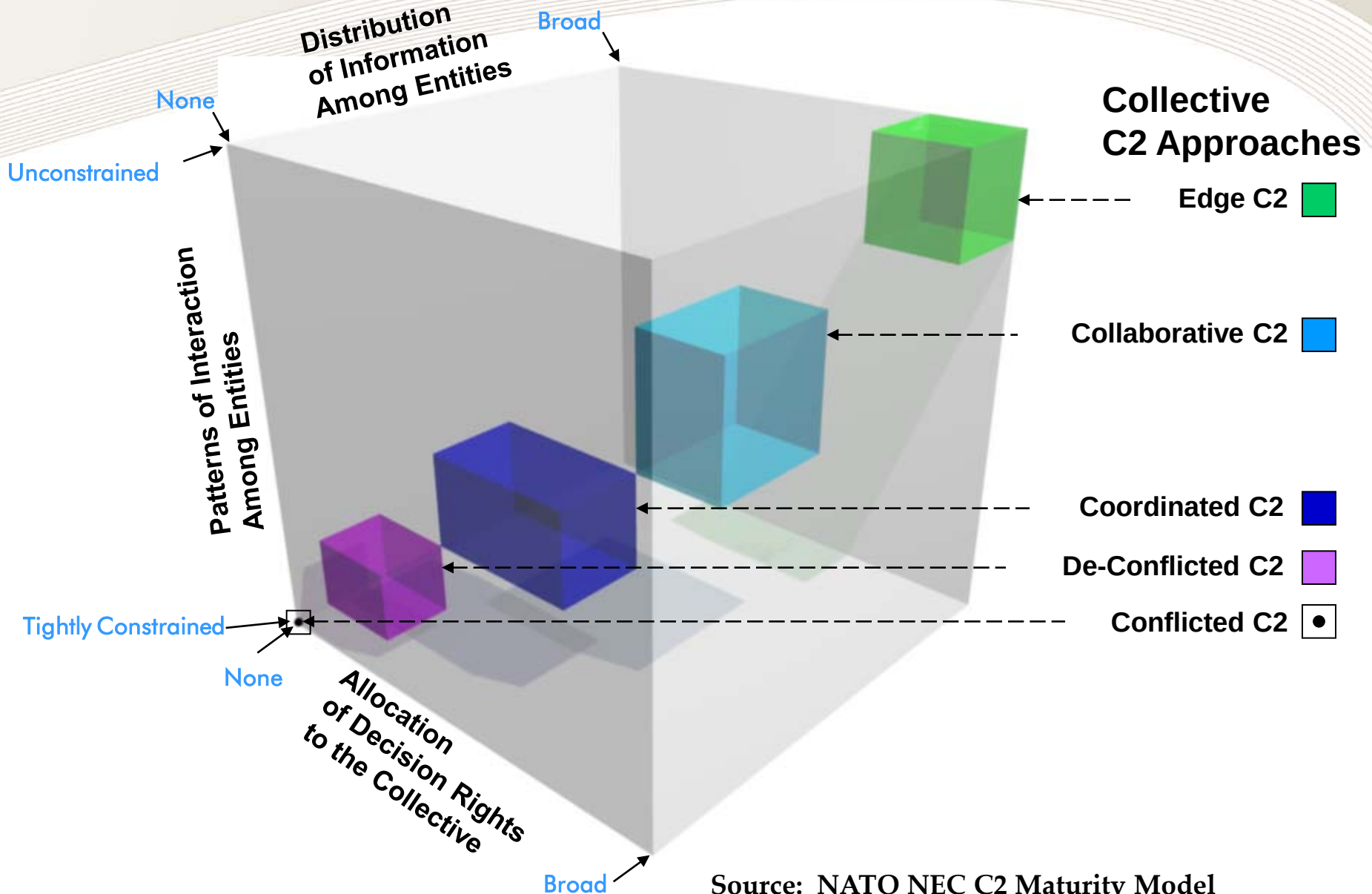
HOWEVER: What C2 Approaches? What advantages?

- There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.
- Developing the “option space” for Command and Control requires that major differences between possible approaches are identified.
 - Centralized v. Decentralized
 - Fixed Vertical Stovepipes v. Dynamic Task Organized
 - Limited information dissemination (need to know) v. broad dissemination (need to share)
- These difference are reflected in the dimensions of the C2 Approach Space (options available)
 - Allocation of Decision Rights (within an entity or to the collective)
 - Patterns of Interaction
 - Distribution of Information

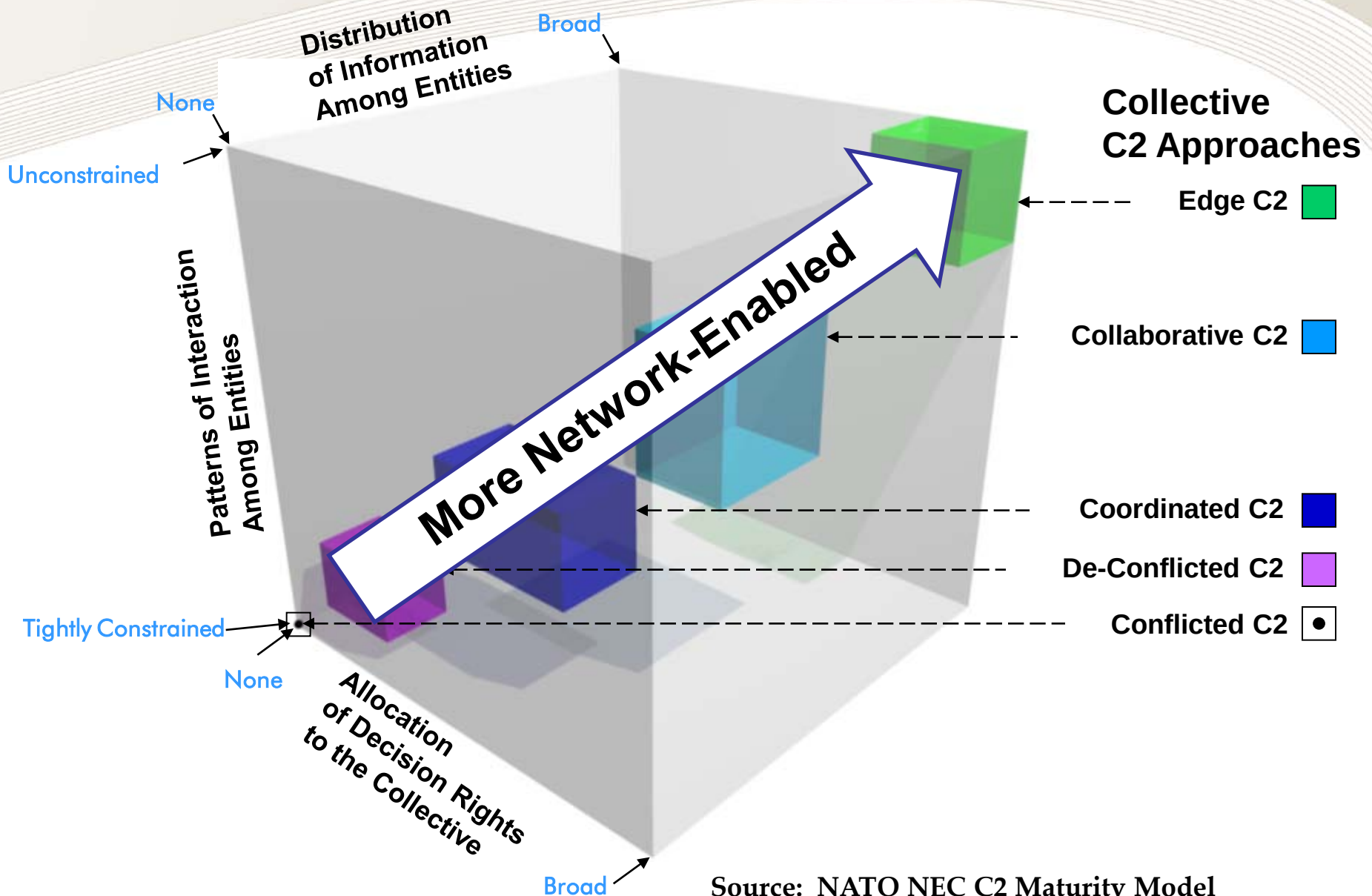
C2 Approach Space



N2C2M2 C2 Approaches



N2C2M2 C2 Approaches



Source: NATO NEC C2 Maturity Model

N2C2M2 Hypotheses

- For a complex endeavor, more network-enabled C2 approaches are **more effective** than less network-enabled C2 approaches.
- For a given level of effectiveness, more network-enabled C2 approaches are **more efficient** than less network-enabled C2 approaches.
- More network-enabled C2 approaches have **more agility** than less network-enabled C2 approaches.

More network-enabled C2 approaches exhibit increased/better levels of:

- Quality of Individual and Shared Information;
- Quality of Individual and Shared Awareness and Understanding;
- **Self-Synchronization;**

Than: less network-enabled C2 approaches.

*The N2C2M2 Agility hypothesis
merits serious exploration because
the increased complexity and
the associated increases in
uncertainty and unpredictability and, therefore,
risk challenges key traditional C2 assumptions*

Agenda

- Paper's Objectives
- From Theory to Practice: Cornerstones
- **C2 Agility Experiments**
- Experimental Results
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Purpose of Experiments

- Experiments constitute a “proof of concept” that we have the foundation in place to begin to operationalize C2 Agility. They show we can:
 - Characterize and represent different approaches
 - Locate them in the C2 Approach Space
 - Define an Endeavor Space (required by Agility Theory)
 - Observe agility-related variables
 - Calculate Agility-related metrics
 - Compare the agility of two C2 Approaches
 - Identify proximately cause(s) of agility or a lack of agility

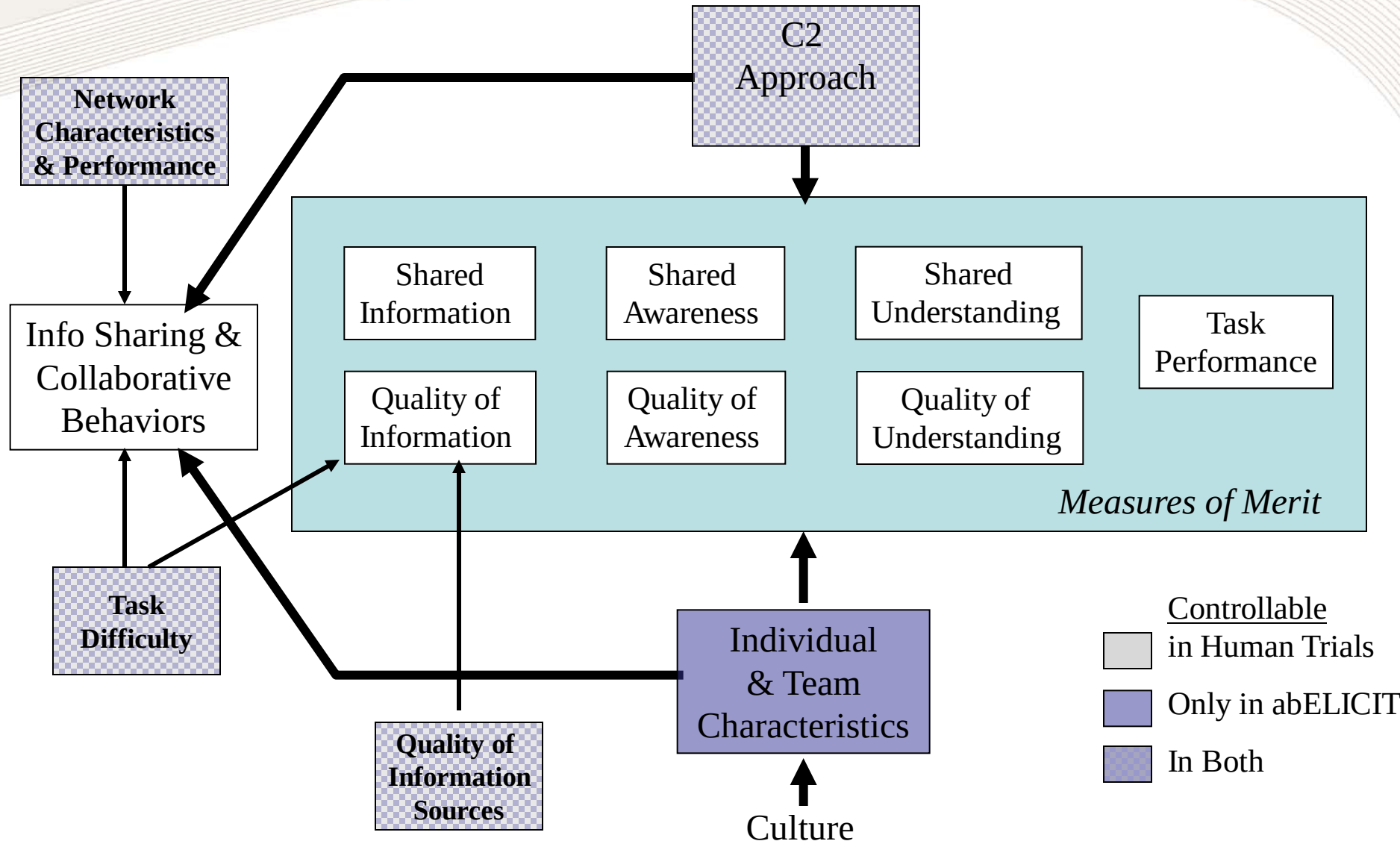
Experimentation platform: ELICIT

Experimental Laboratory for
Investigating Collaboration, Information-sharing, and Trust

- Command and Control Research Program (CCRP) sponsored the design and development of the ELICIT platform to facilitate experimentation focused on information, cognitive, and social domain phenomena
- ELICIT is a web-accessible experimentation environment supported by software tools and instructions / procedures
- abELICIT is an agent-based version of the ELICIT platform

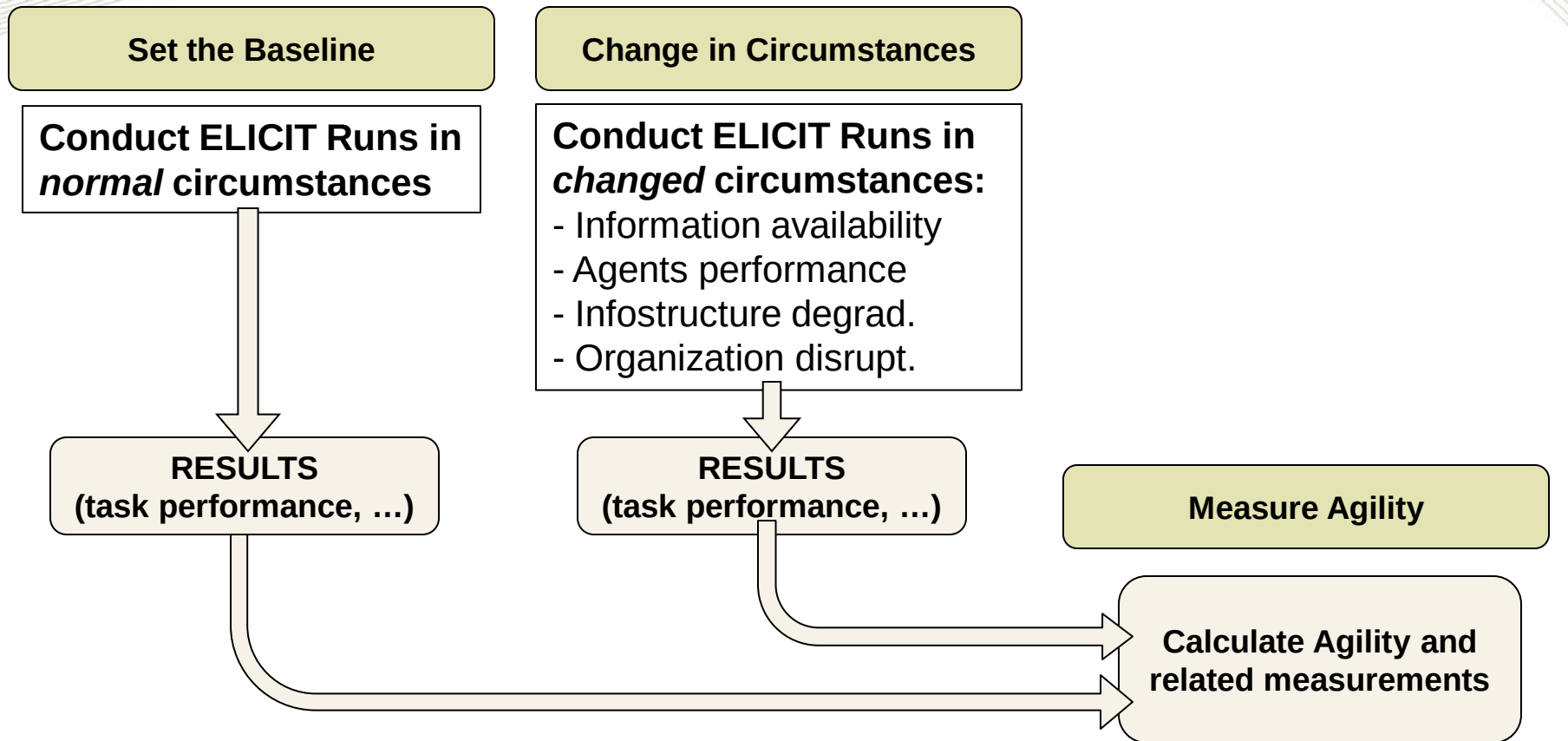
- The goal of each set of participants is to build situational awareness and identify the who, what, when, and where of a pending attack
 - Factoids are periodically distributed to participants; each participant receives a small subset of the available factoids
 - No one is given sufficient information to solve without receiving information from others
 - Participants can share factoids directly with each other, post factoids to websites, and by “keyword directed” queries
 - Participants build awareness and shared awareness by gathering and cognitively processing factoids
- The receiving, sharing, posting, and seeking of factoids and the nature of the interactions between and among participants can be constrained
- Participants can be “organized” and motivated in any number of ways
- Various stresses can be applied (e.g. communications delays and losses)
- Software-Agents are used instead of humans

Controllable Variables



- **Objective** : observe the agility of a range of C2 Approaches options.
- **Methodology**
 - A set of C2 Approach Options were defined and instantiated
 - Measures of Effectiveness, Timeliness, and Efficiency (MoMs) were defined (dimensions “acceptable” mission performance)
 - An Endeavor Space was created composed of:
 - A set of mission challenges related to the timeliness of information availability
 - A range of Agent capabilities
 - A range of Infostructure conditions
 - A range of levels of organizational disruption
 - abELICIT runs were made that spanned Endeavor Space for each of the C2 Approach Options

- Methodology

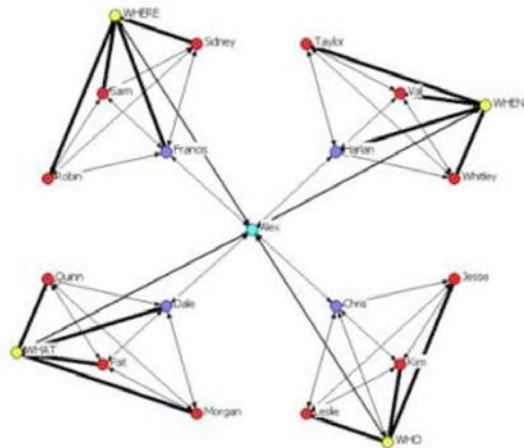


Absolute agility (percentage of area in endeavor space in which an entity can operate successfully)

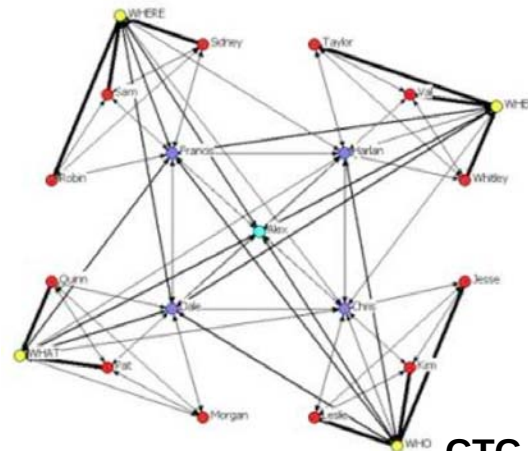
- **Manipulations**

Manipulations	Description	Agility component to observe
Key Information Availability	The point at which key information is made available is varied. When information is provided later there is less time to accomplish the task.	Versatility (over problem difficulty) Responsiveness
Agent Performance	Three levels of agent performance were simulated to include: 'lower performing', 'normal performing' and 'high performing'.	Versatility (of organization) Responsiveness
Infostructure Degradation	Infostructure performance was degraded by removing links between nodes and websites.	Resilience (of infostructure) Responsiveness
Organization Disruption	The organization will be disrupted by eliminating nodes (i.e., individuals).	Resilience (of organization) Responsiveness

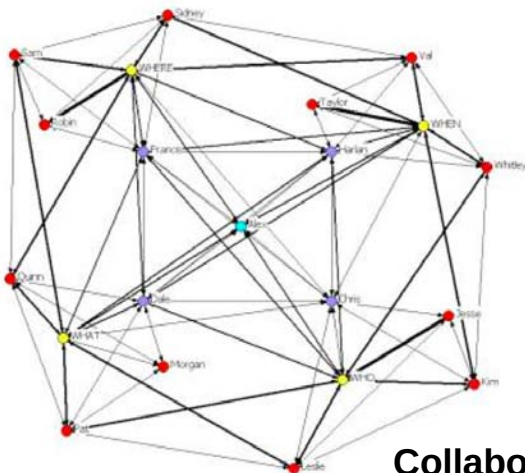
- C2 Approaches Instantiated**



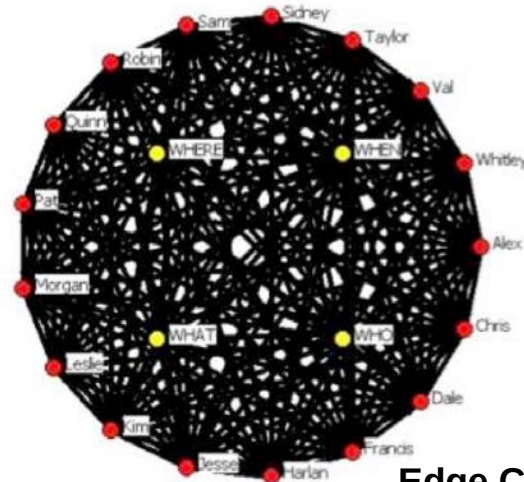
Coordinated C2



CTC-TL Collaborative C2

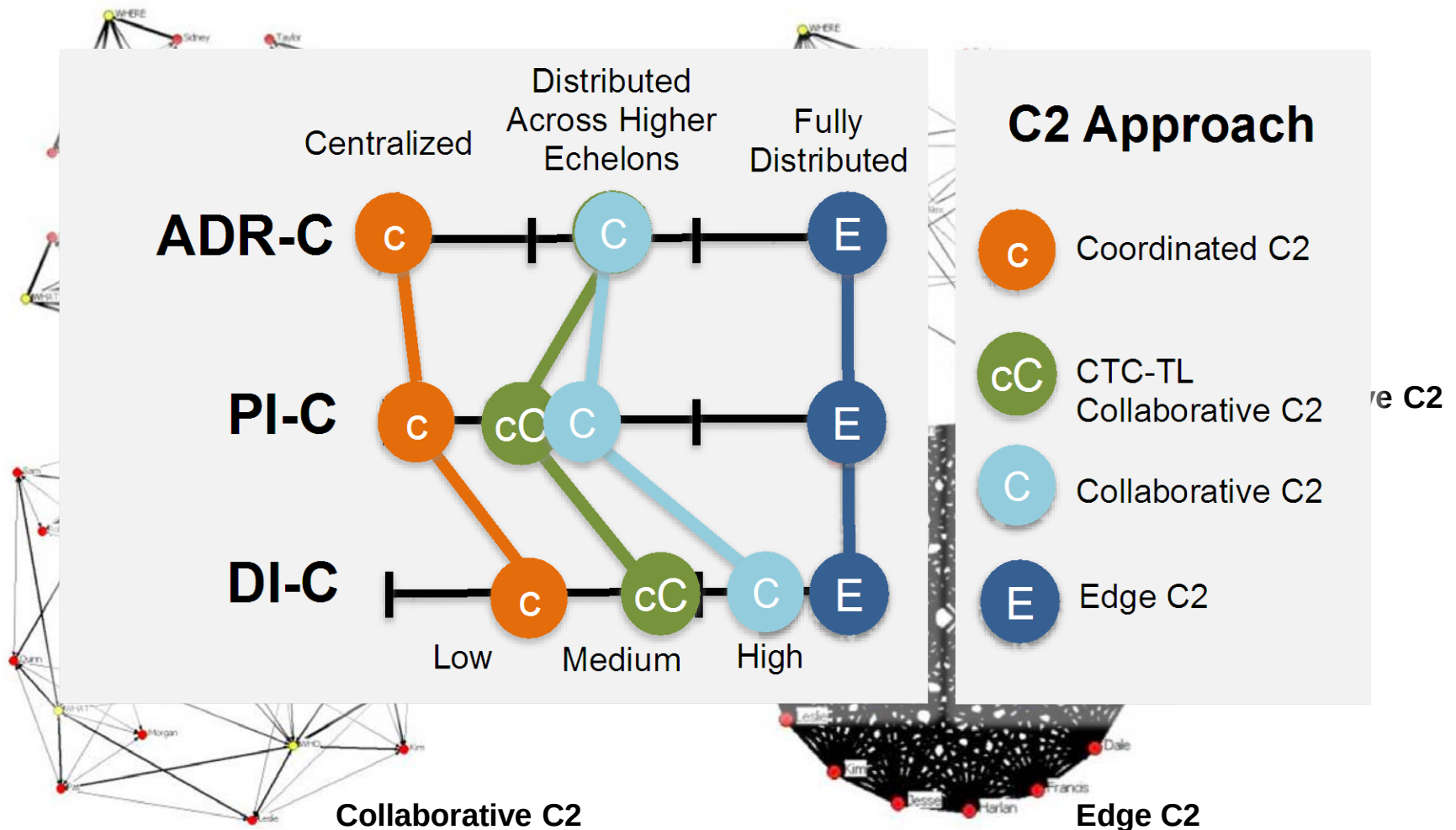


Collaborative C2

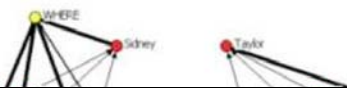


Edge C2

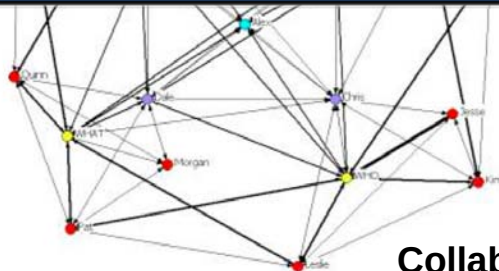
- **C2 Approaches Instantiated (Position in the C2 Approach Space)**



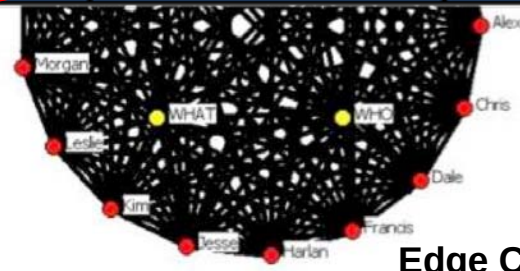
- C2 Approaches Instantiated (BASELINE Results)



C2 Approach	Average Correctness	Maximum Timeliness	Effectiveness*
Coordinated C2	0.06	0.17	1
CTC-TL Collaborative C2	0.29	0.20	1
Collaborative C2	0.35	0.40	1
Edge C2	1.00	0.20	1



Collaborative C2



Edge C2

* C2 Approach Specific

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Results of Experiments

- **Key Information Availability – Agility measurements**

Coordinated C2

CTC-TL Collaborative C2

Collaborative C2

Edge C2

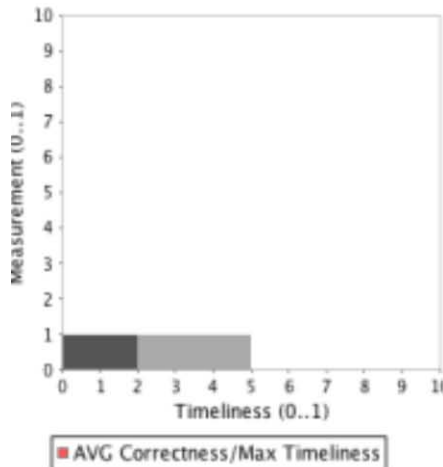
More network-enabled C2 Approaches are more Agile than less network-enabled approaches.

C2 Approach	Absolute Agility
Coordinated C2	0.05
CTC-TL Collaborative C2	0.14
Collaborative C2	0.2
Edge C2	0.6

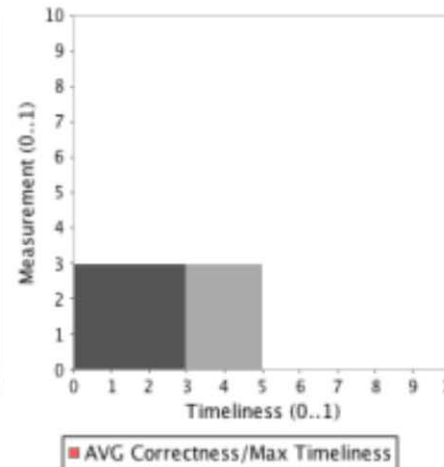
Results of Experiments

- Impact of Agents Performance – Agility measurements**

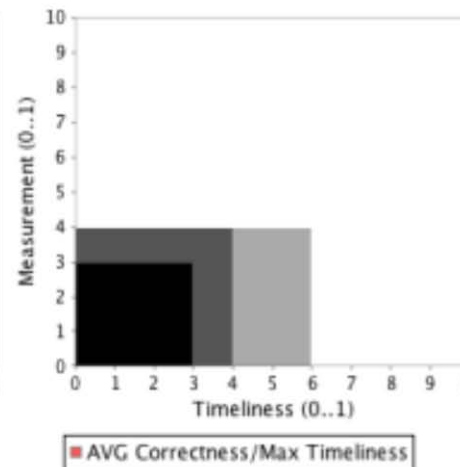
Coordinated C2



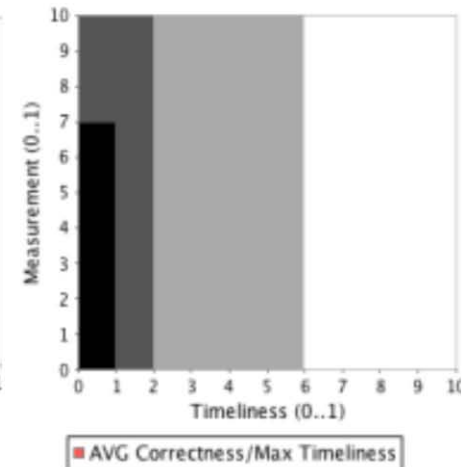
CTC-TL Collaborative C2



Collaborative C2



Edge C2



More network-enabled C2 Approaches are more Agile
than less network-enabled approaches.

C2 Approach	Absolute Agility
Coordinated C2	0.02
CTC-TL Collaborative C2	0.07
Collaborative C2	0.16
Edge C2	0.29

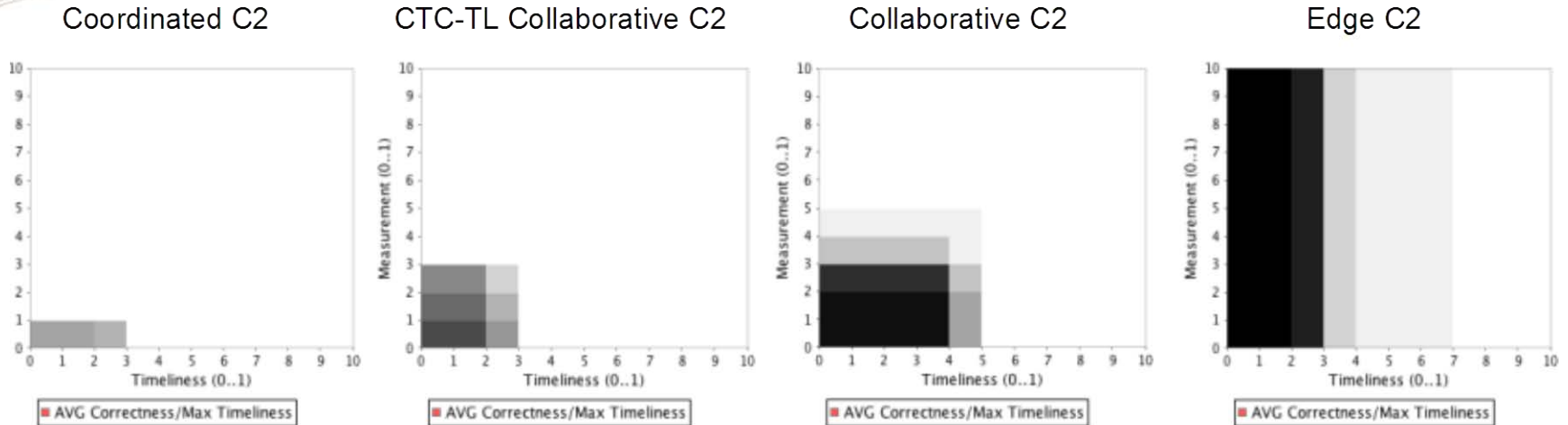
Results of Experiments

- **Impact of Infostructure Degradation – Performance measurements**

C2 Approach	Average Correctness		
	Basel.	Mean	Downg.
Coordinated C2	0.06	0.02	0.04
CTC-TL Collaborative C2	0.29	0.15	0.15
Collaborative C2	0.35	0.28	0.08
Edge C2	1.00	1.00	0.00

Results of Experiments

- Impact of Infostructure Degradation – Agility measurements



More network-enabled C2 Approaches are more Agile than less network-enabled approaches.

C2 Approach	Absolute Agility
Coordinated C2	0.01
CTC-TL Collaborative C2	0.04
Collaborative C2	0.13
Edge C2	0.32

Results of Experiments

- **Impact of Organization Disruption – Performance measurements**

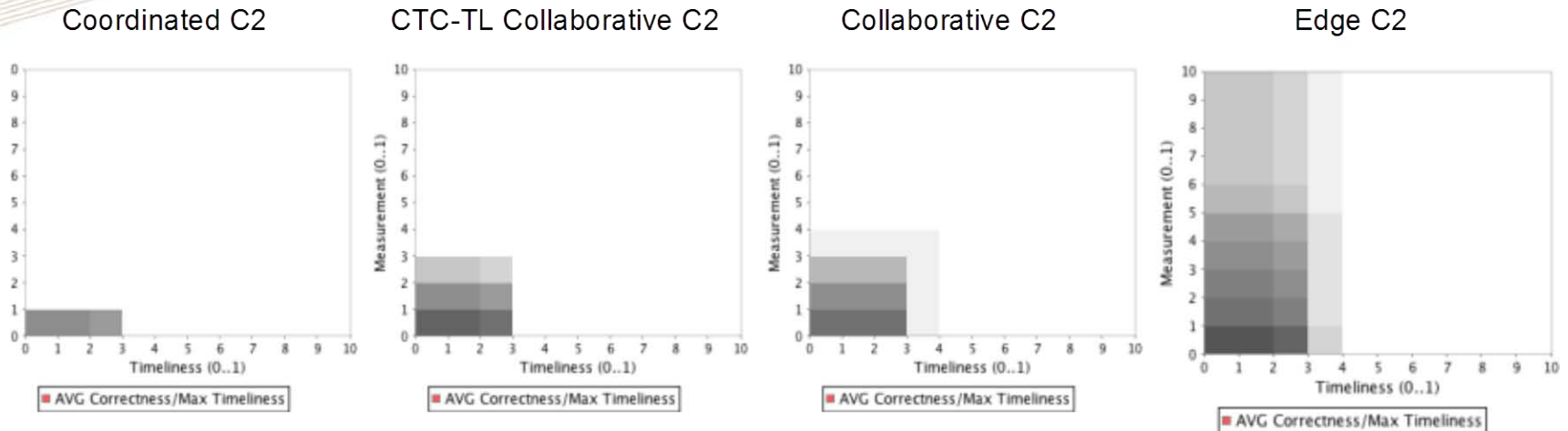
C2 Approach	Average Correctness		
	Basel.	Mean	Downg.
Coordinated C2	0.06	0.02	0.04
CTC-TL Collaborative C2	0.29	0.09	0.20
Collaborative C2	0.35	0.09	0.26
Edge C2	1.00	0.30	0.70

— Baseline performance

— 1 node down performance (mean value)

Results of Experiments

- Impact of Organization Disruption – Agility measurements**



More network-enabled C2 Approaches are more Agile than less network-enabled approaches.

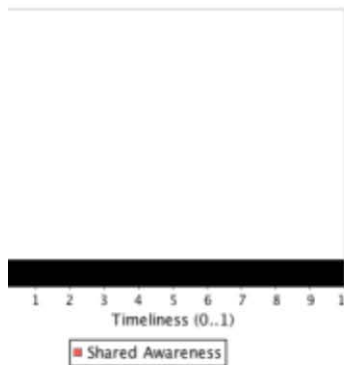
C2 Approach	Absolute Agility
Coordinated C2	0.01
CTC-TL Collaborative C2	0.04
Collaborative C2	0.04
Edge C2	0.11

Results of Experiments

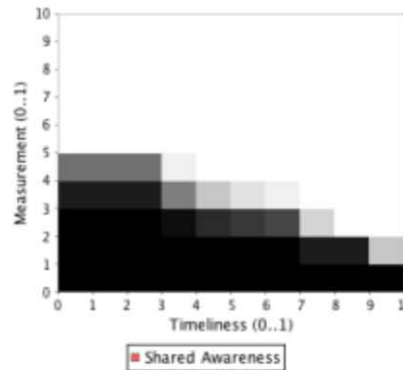
- Impact of Organization Disruption – Performance Maps

Shared Awareness Performance Map

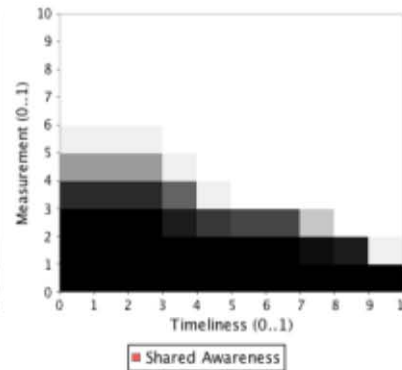
Coordinated C2



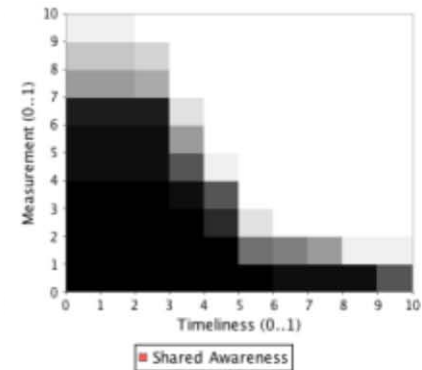
CTC-TL Collaborative C2



Collaborative C2

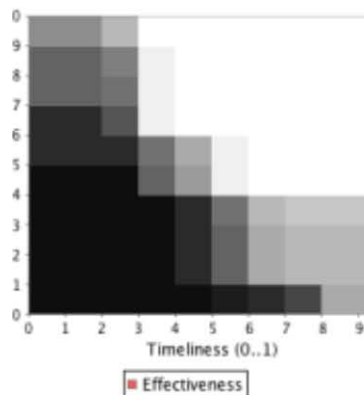


Edge C2

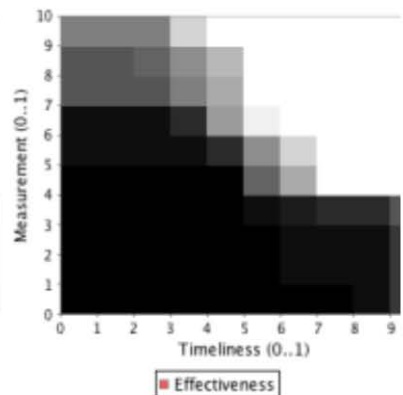


Effectiveness Performance Map

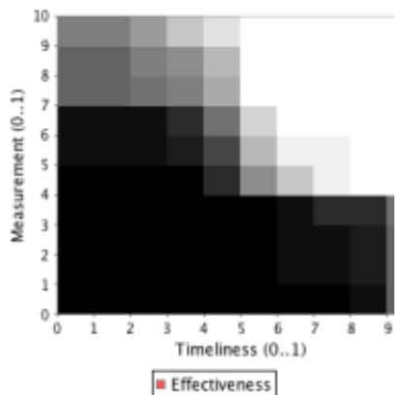
Coordinated C2



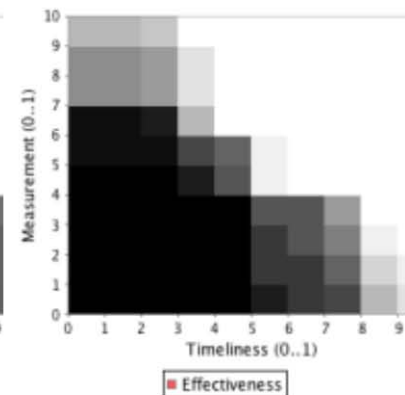
CTC-TL Collaborative C2



Collaborative C2



Edge C2

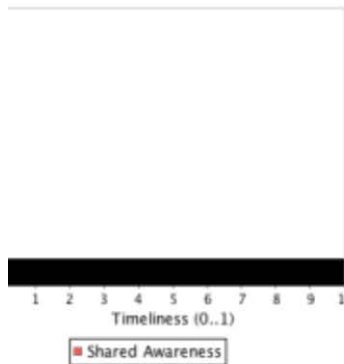


Results of Experiments

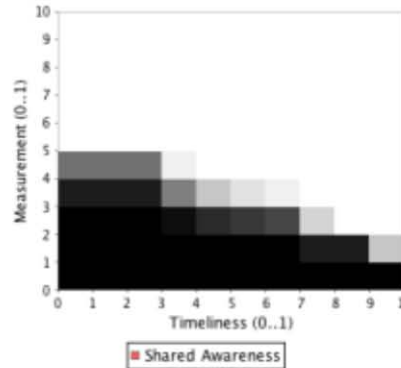
- Impact of Organization Disruption – Performance Maps

Shared Awareness Performance Map

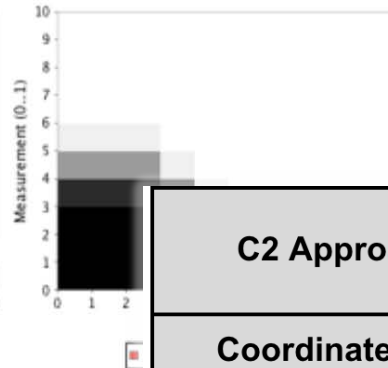
Coordinated C2



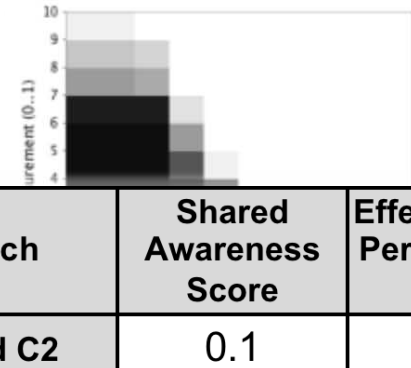
CTC-TL Collaborative C2



Collaborative C2



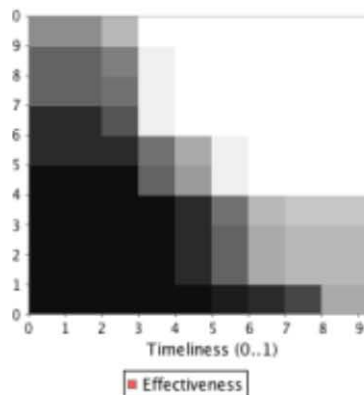
Edge C2



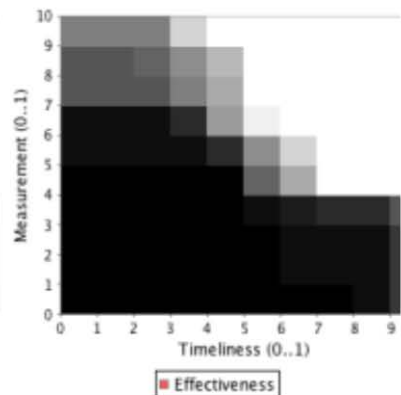
C2 Approach	Shared Awareness Score	Effectiveness Performance Score
Coordinated C2	0.1	0.41
CTC-TL Collaborative C2	0.31	0.61
Collaborative C2	0.3	0.59
Edge C2	0.37	0.44

Effectiveness Performance Map

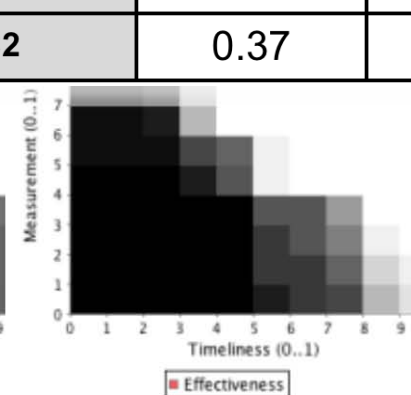
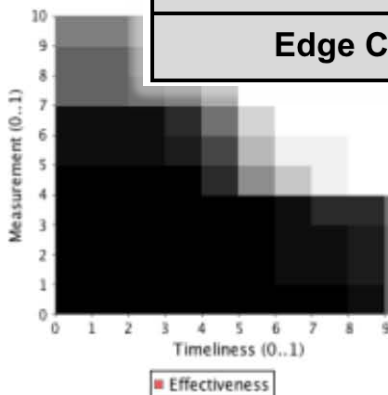
Coordinated C2



CTC-TL Collaborative C2



Colla



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Conclusions

- A sufficient foundation is in place to explore C2 Agility using cases studies and experiments
- Ways to measure and visualize Agility (and its enablers) were proposed:
 - Agility Maps
 - Performance Maps
- More networked-enabled approaches to C2 achieved higher levels of shared awareness
- More networked-enabled approaches to C2 were more agile

Way Ahead

- More experimentation is needed, particularly with actual (i.e., real-world) organizations and systems
- Further engage with those in the education and training communities
- Need to improve our simulation capabilities

Bibliography

- [1] Alberts, David S. 2011. *The Agility Advantage: A survival guide for complex enterprises and endeavors*. CCRP Publication Series.
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- [3] Manso, Marco. 2012. "N2C2M2 Validation using abELICIT: Design and Analysis of ELICIT runs using software agents" Paper presented at the 17th ICCRTS, Fairfax, USA, June 19-21.
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- [6] Ruddy, Mary. *ELICIT 2.2.1 Web-based Software Guide for Human Experiment Directors*. Parity Communications, Inc., Dec 2008. Paper presented at the 14th ICCRTS, Washington DC, USA, 2009.
- [7] Ruddy, M, *ELICIT 2.5 Software Guide*, CCRP, August, 2011

Thank You !

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dalberts@ida.org

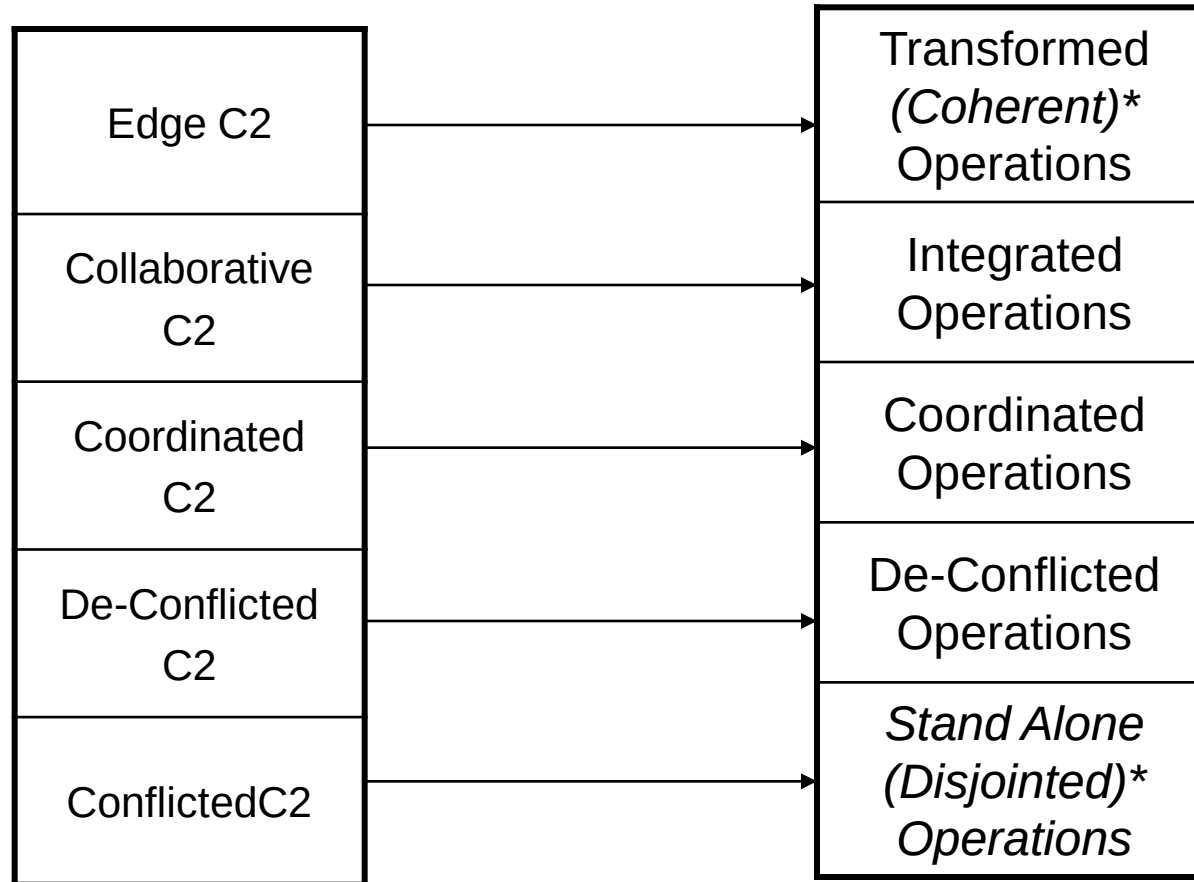
Marco Manso
marco@marcomanso.com

Annexes and Additional Material

C2 Approach → NNEC Maturity

C2 Approaches

NNEC Capability Levels





C2 Approaches and C2 Approach Dimensions

(context is a collection of civil-military entities)

C2 Approach	Allocation of Decision Rights <i>to the Collective</i>	Patterns of Interaction Among Participating Entities	Distribution of Information (Entity Information Positions)
Edge C2	Not Explicit, Self- Allocated (Emergent, Tailored, and Dynamic)	Unlimited As Required	All Available and Relevant Information Accessible
Collaborative C2	Collaborative Process and Shared Plan	Significant Broad	Additional Information Across Collaborative Areas/Functions
Coordinated C2	Coordination Process and Linked Plans	Limited and Focused	Additional Information About Coordinated Areas/Functions
De-Conflicted C2	Establish Constraints	Very Limited Sharply Focused	Additional Information About Constraints and Seams
Conflicted C2	None	None	Organic Information

Entity Cluster

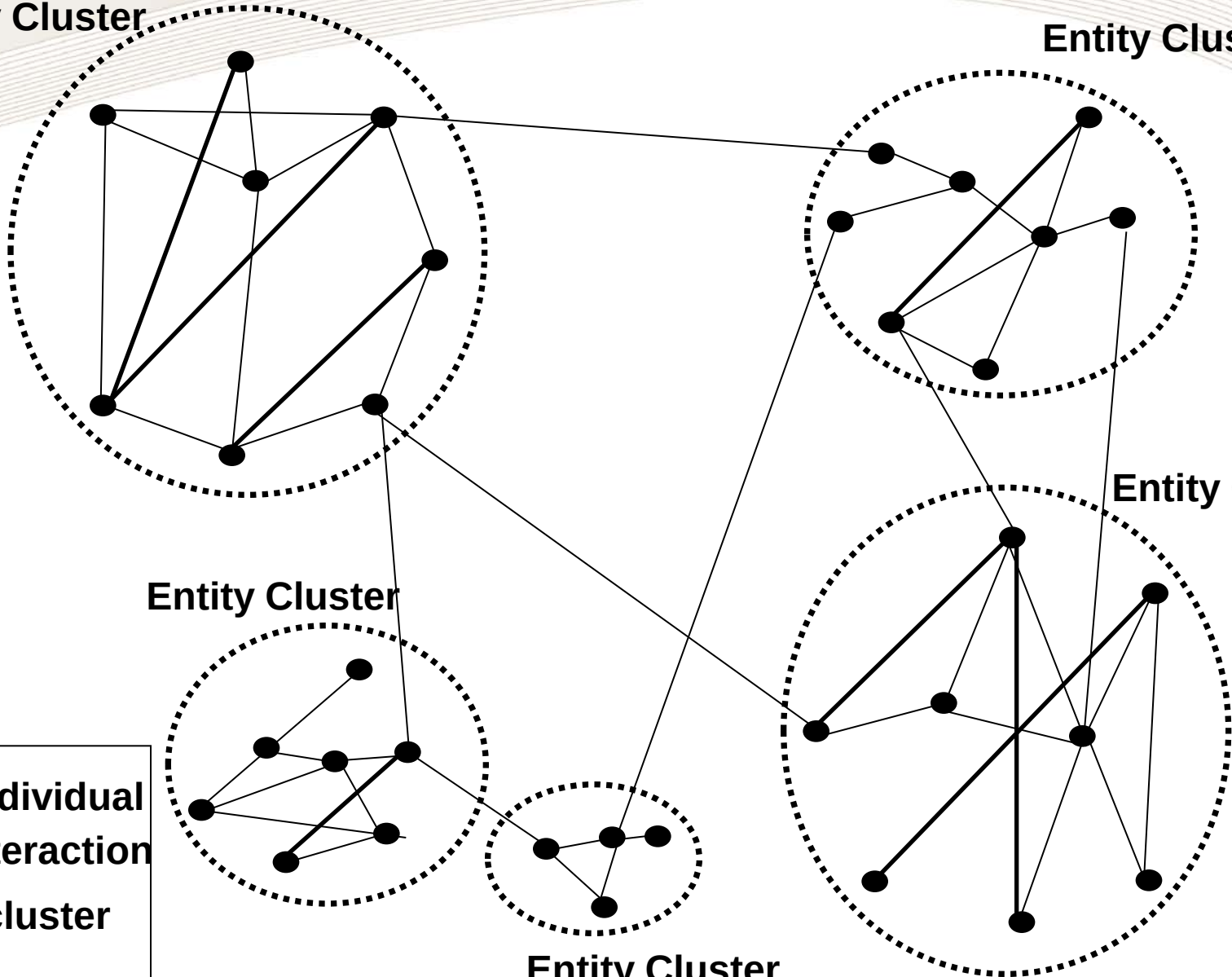
Entity Cluster

Entity Cluster

Entity Cluster

Entity Cluster

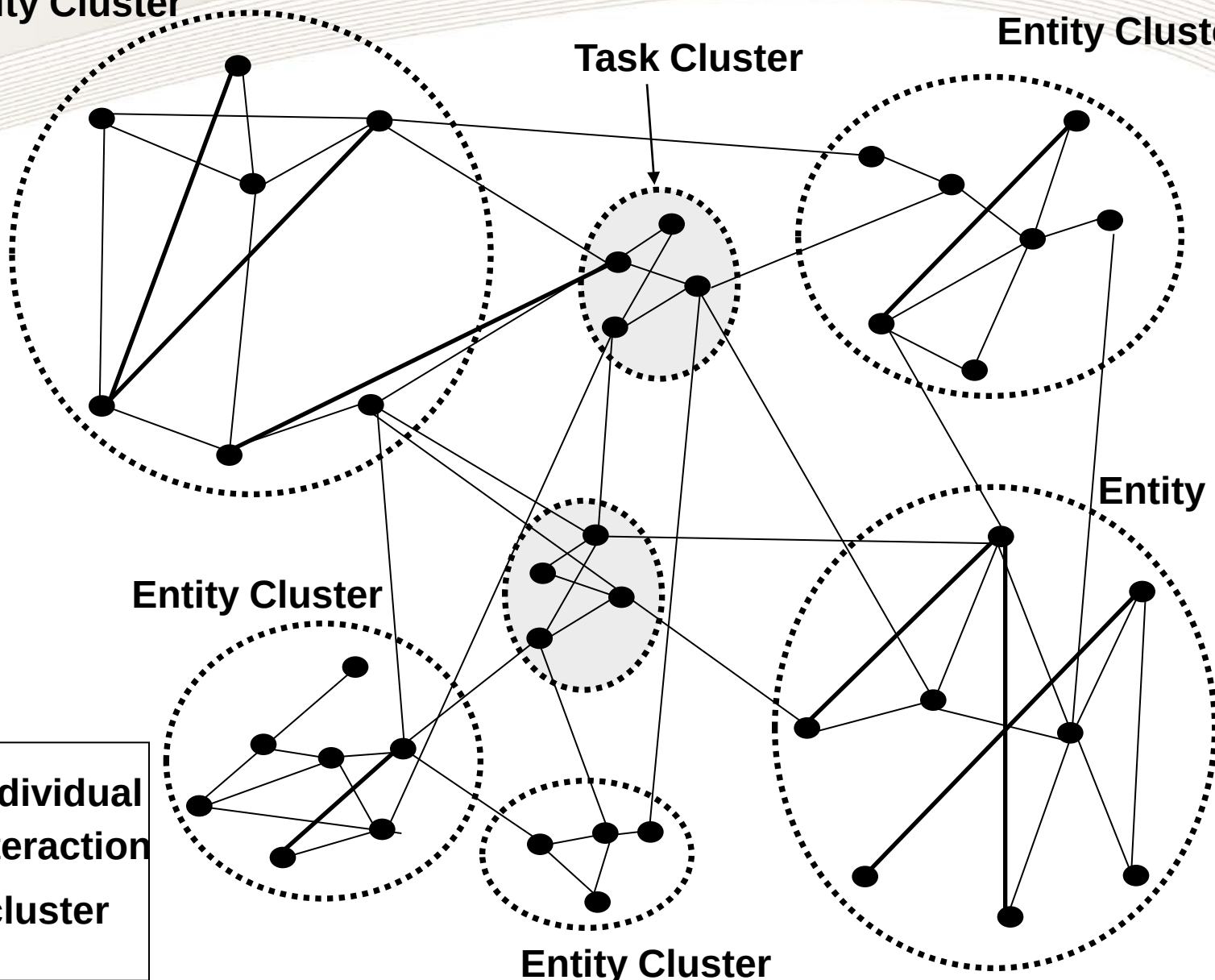
- individual
- interaction
- cluster



Entity Cluster

Task Cluster

Entity Cluster

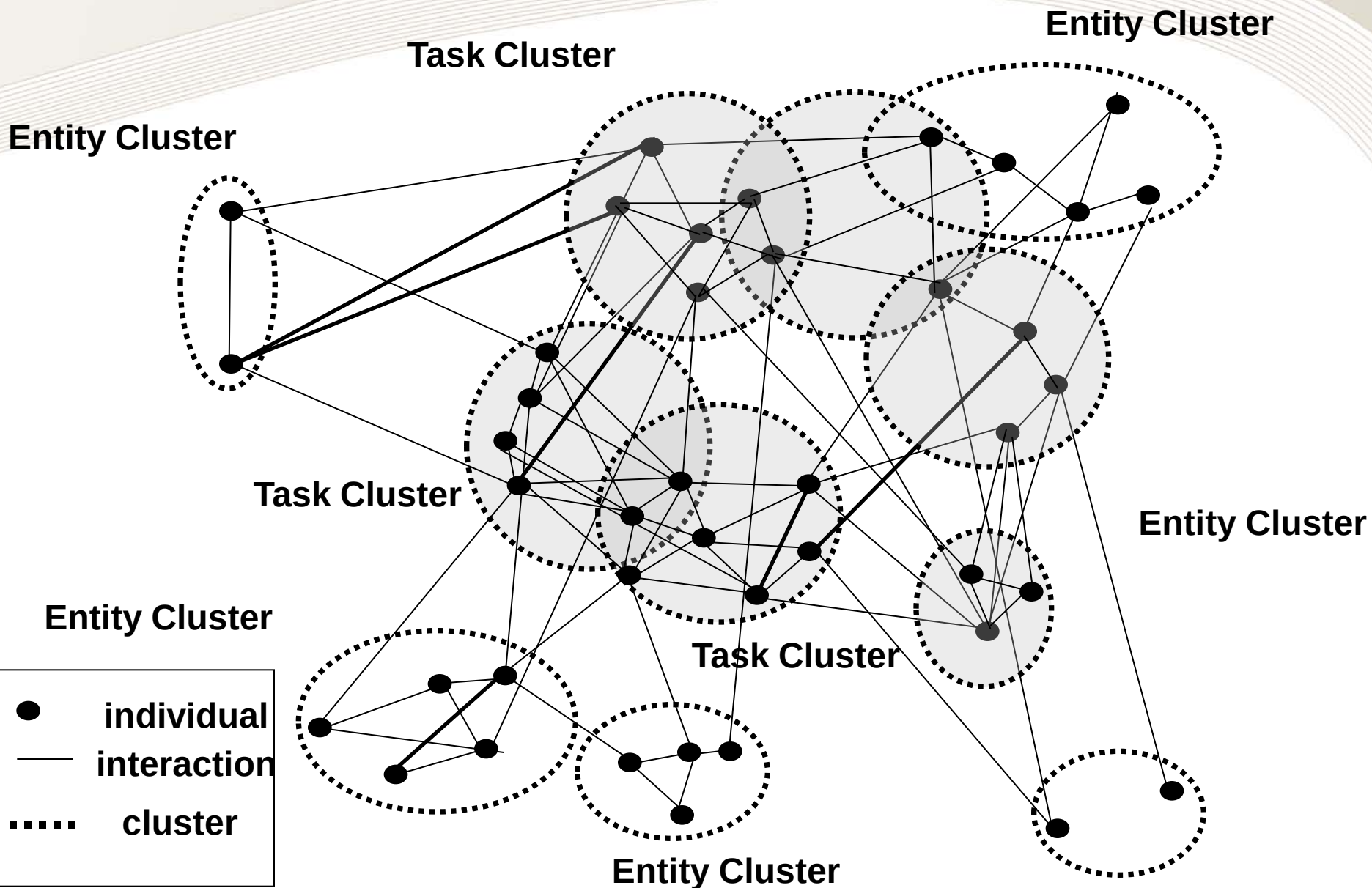


Entity Cluster

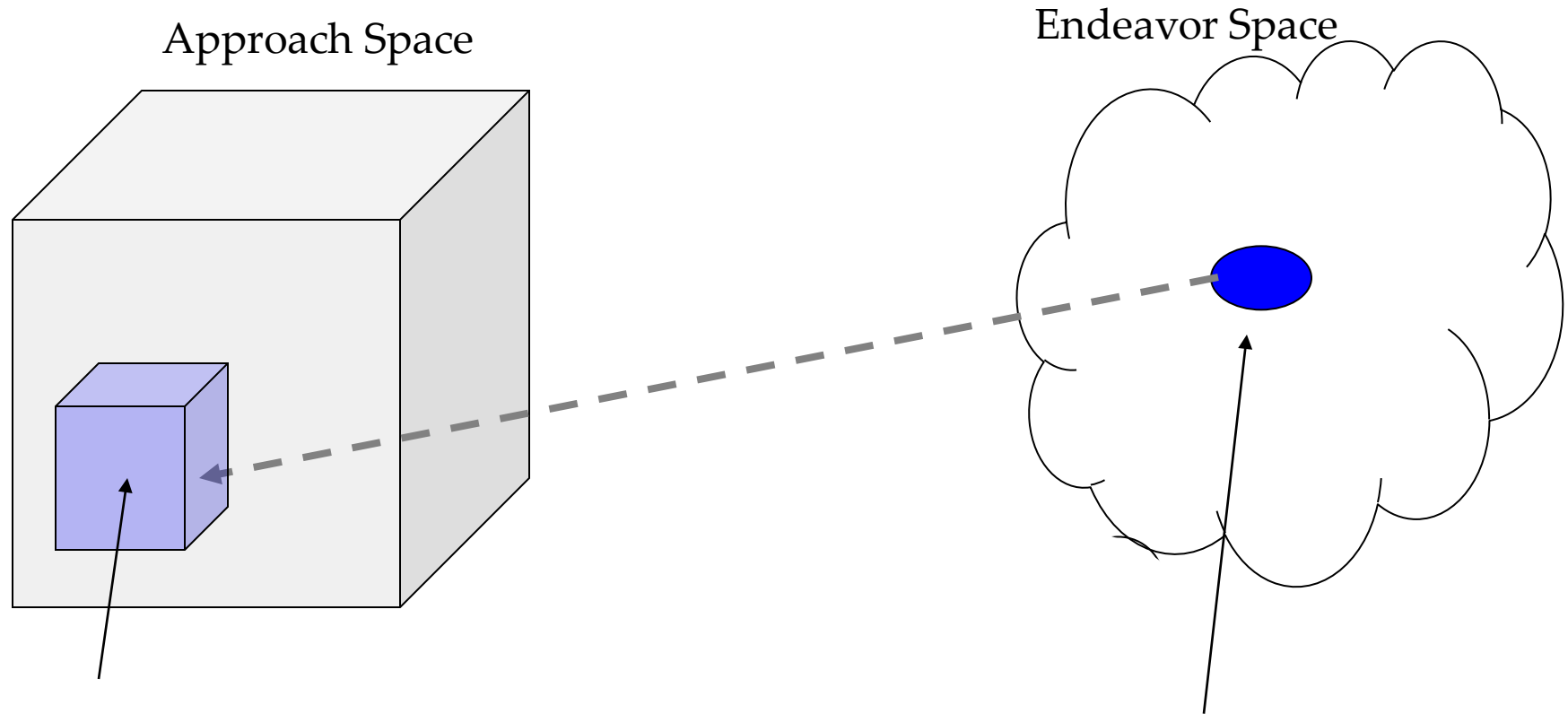
Entity Cluster

Entity Cluster

Patterns of Interactions: Edge C2



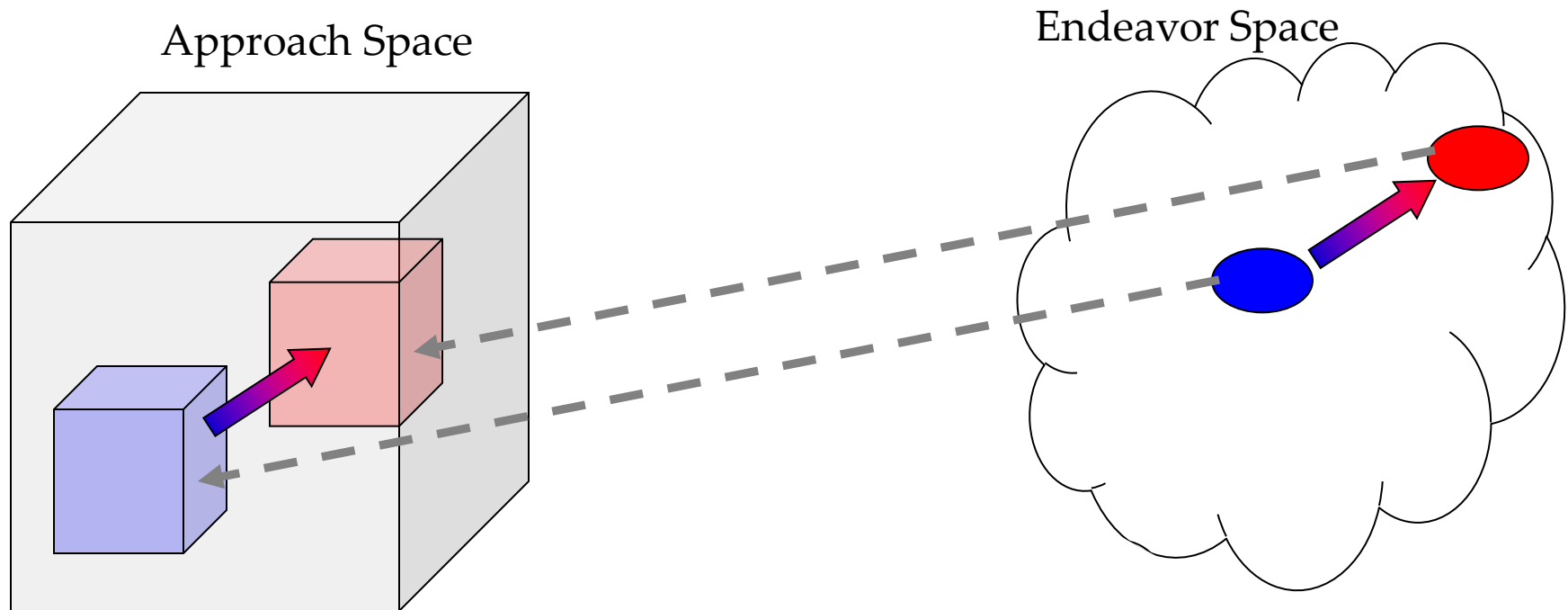
C2 Agility



This is a most appropriate C2 Approach for this particular set of circumstances

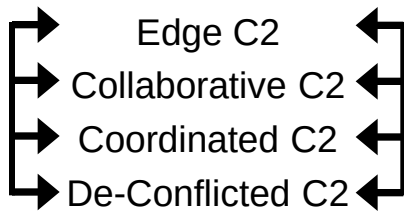
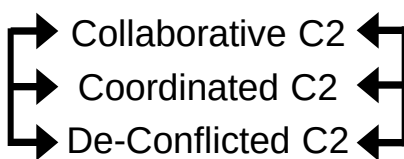
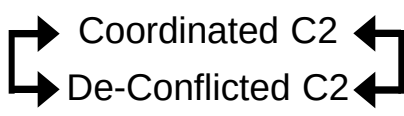
C2 Agility

When circumstances change, a different approach might be more appropriate



C2 Agility involves recognizing the significance of a change in circumstances, understanding the most appropriate C2 Approach for the circumstance and being able to transition to this approach.

Net-enabled C2 → C2 Maturity → C2 Agility

C2 Maturity Levels	Contents of C2 Toolkit	C2 Approach Decision Requirement	Transition Requirements
Level 5	Edge C2 Collaborative C2 Coordinated C2 De-Conflicted C2	Emergent	
Level 4	Collaborative C2 Coordinated C2 De-Conflicted C2	Recognise 3 situations and match to appropriate C2 approach	
Level 3	Coordinated C2 De-Conflicted C2	Recognise 2 situations and match to appropriate C2 approach	
Level 2	De-Conflicted C2	N/A	None
Level 1	Conflicted C2	N/A	None

C2 Agility

- Experimentation with live groups of individuals is time consuming and expensive.
- This limits the number of runs that can be made.
- This, in turn, limits the exploration of treatment effects.
- Therefore, the CCRP decided to develop agents that could be used in the place of people.
- abELICIT is an all agent-based simulation model that replaces the people with software agents and uses the ELICIT experimentation platform.
- abELICIT is capable of mixing agents and humans in same experimental trial. [but this capability has only been used to test ELICIT]

- Agents look like a human to human participants
- Configurable behaviors/personalities using 40+ parameters
- Able to perform all human actions
 - Post factoids to website
 - Pull factoids from websites
 - Share factoids with other participants
 - Identify adversary attack
- Agents create “mental models” of the situation in the form of truth tables and “judgments” with regard to information sources as a result of factoids received or retrieved and the interactions they have with others