C2 Agility

a tutorial and review of SAS-085 Findings

Contributing Nations











Presenters

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- Dr. Alberto Tremori, University of Genoa

Agenda

- Objectives
- Basics of Agility
- Evolution of Command and Control
- C2 Agility
- C2 Agility Hypotheses
- Validation
- Case Studies
- Campaign of Experimentation
- Summary of Findings, Conclusions, and Way Ahead

Objectives

- At the end of the day, participants should be able to explain to others:
  - the concept of C2 agility
  - why it is an critical capability, and
  - its implications for the art and practice of command and control

- At the end of the day, SAS-085 members should be able to:
  - assess how well they communicated the concepts
  - identify ways to improve their final report

Basics of Agility

- Definition of Agility
- Measuring Agility
- Passive v. (pro)Active
- Enablers of Agility
- Manifest v. Potential Agility
- Requisite Agility

What is Agility?

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

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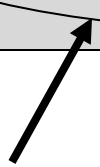
The concept of agility applies to:

organizations, processes, individuals, systems, equipment, and facilities

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
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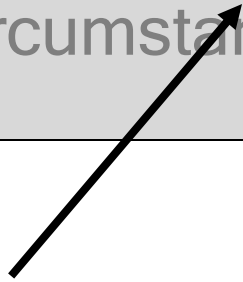
changes in circumstances



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

What is Agility?

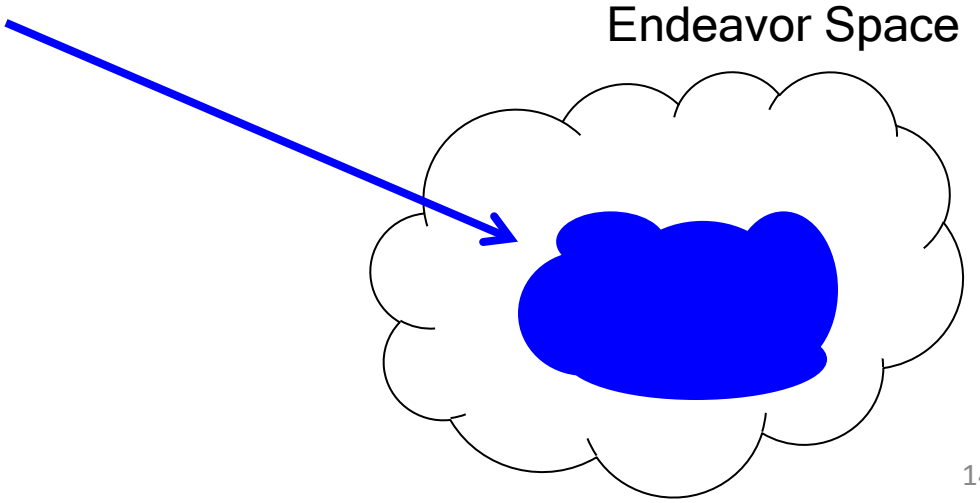
Agility is the capability
to successfully
effect, cope with and/or exploit
changes in circumstances

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

Measuring Agility

- The degree of agility possessed by an entity is a function of its ability to successful operate over an appropriate set of circumstances (Endeavor Space)
- A scalar measure of agility is defined as the area of the region in the Endeavor Space where an entity can successfully operate

$$\text{Agility} = \frac{\text{Area of } \bullet}{\text{Area of } \circ}$$

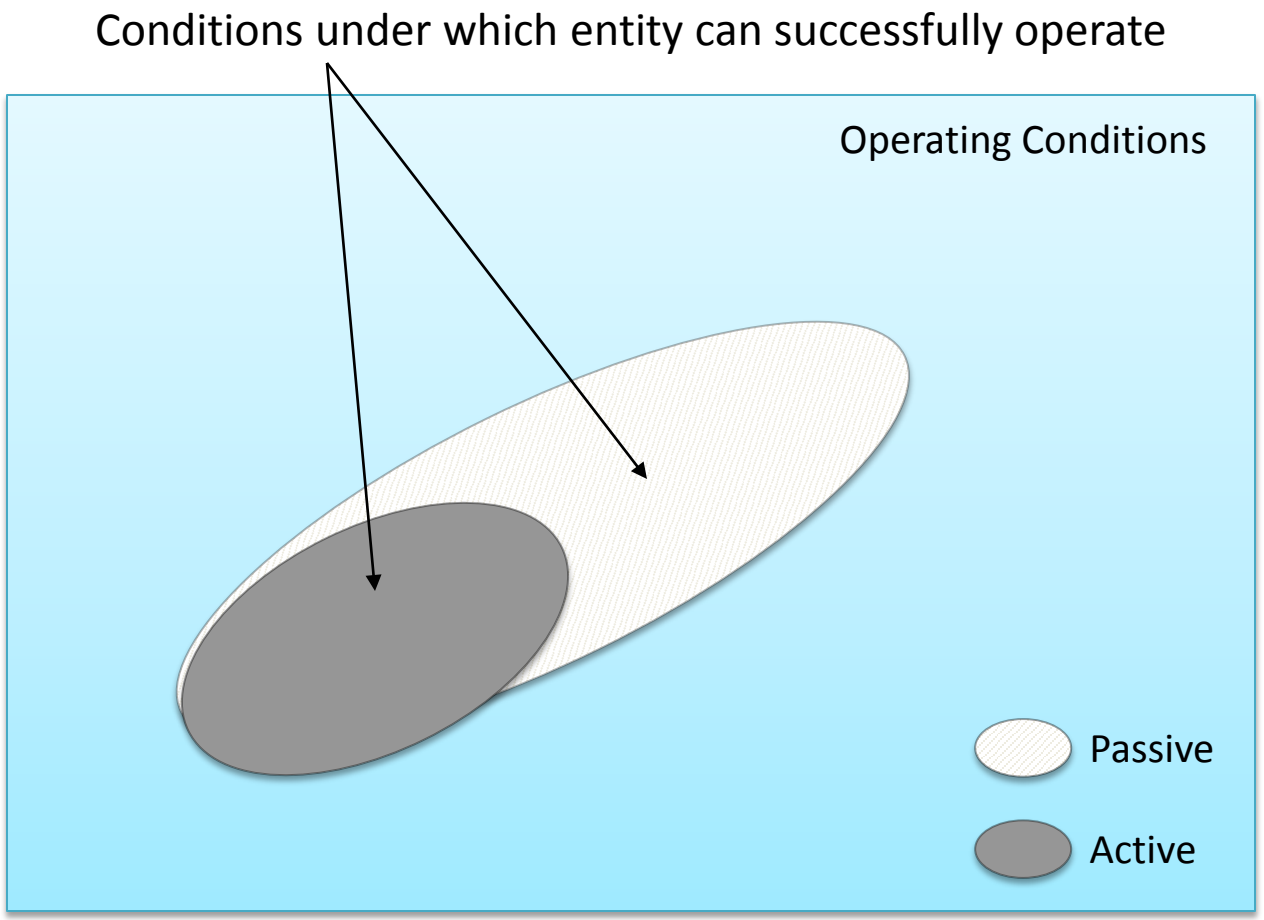


Passive v. Active Agility

- Passive Agility - the set of circumstances, an operating envelope, where an entity can successfully operate without the need for intervention. This may be a result of design or serendipity.

- Active Agility – success depends upon the entity taking some action in anticipation of, or in response to, a change in circumstances in order to prevent a loss of effectiveness that results in failure.

Value-Added of Active Agility



Source: The Agility Advantage

Enablers of Agility

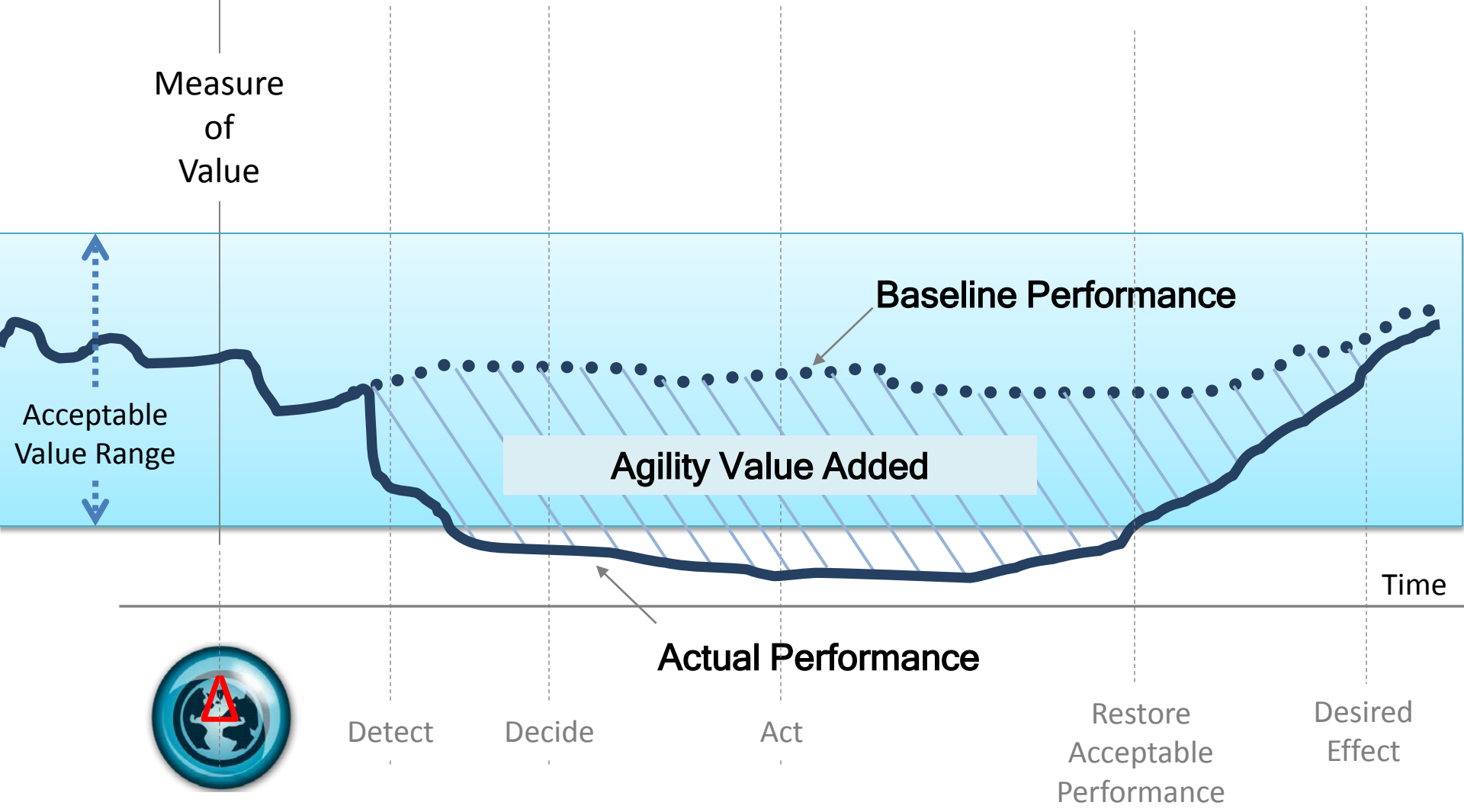
- Responsiveness
- Versatility
- Flexibility
- Resilience
- Adaptiveness
- Innovativeness

The contributions of these enablers to agility are not additive

Responsiveness

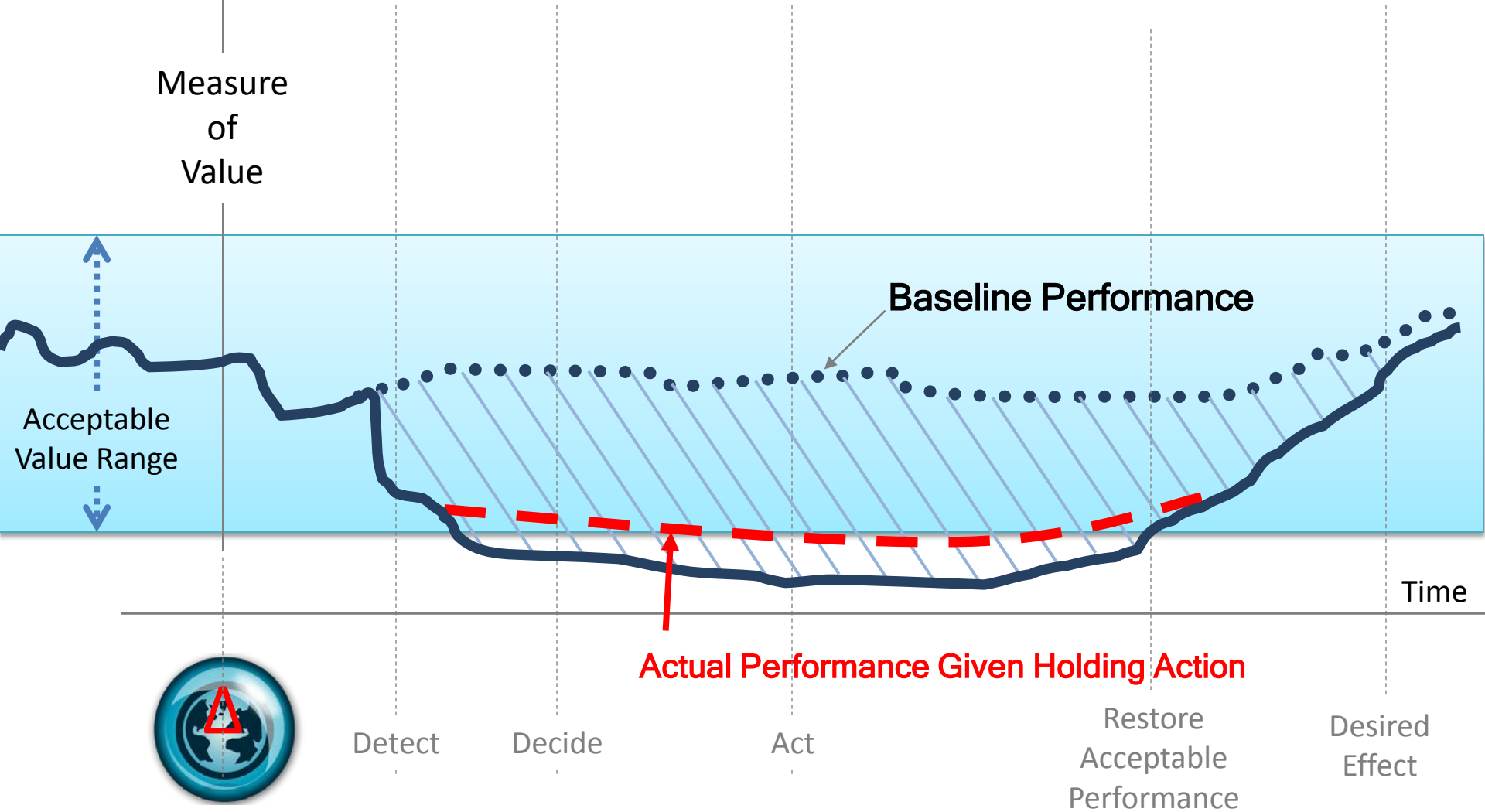
- Responsiveness is an essential enabler of Active Agility.
- Responsiveness is a reflection of the timeliness of the intervention(s).
- The efficacy of the intervention is a function of all six of the enablers of agility.

Anatomy of Responsiveness



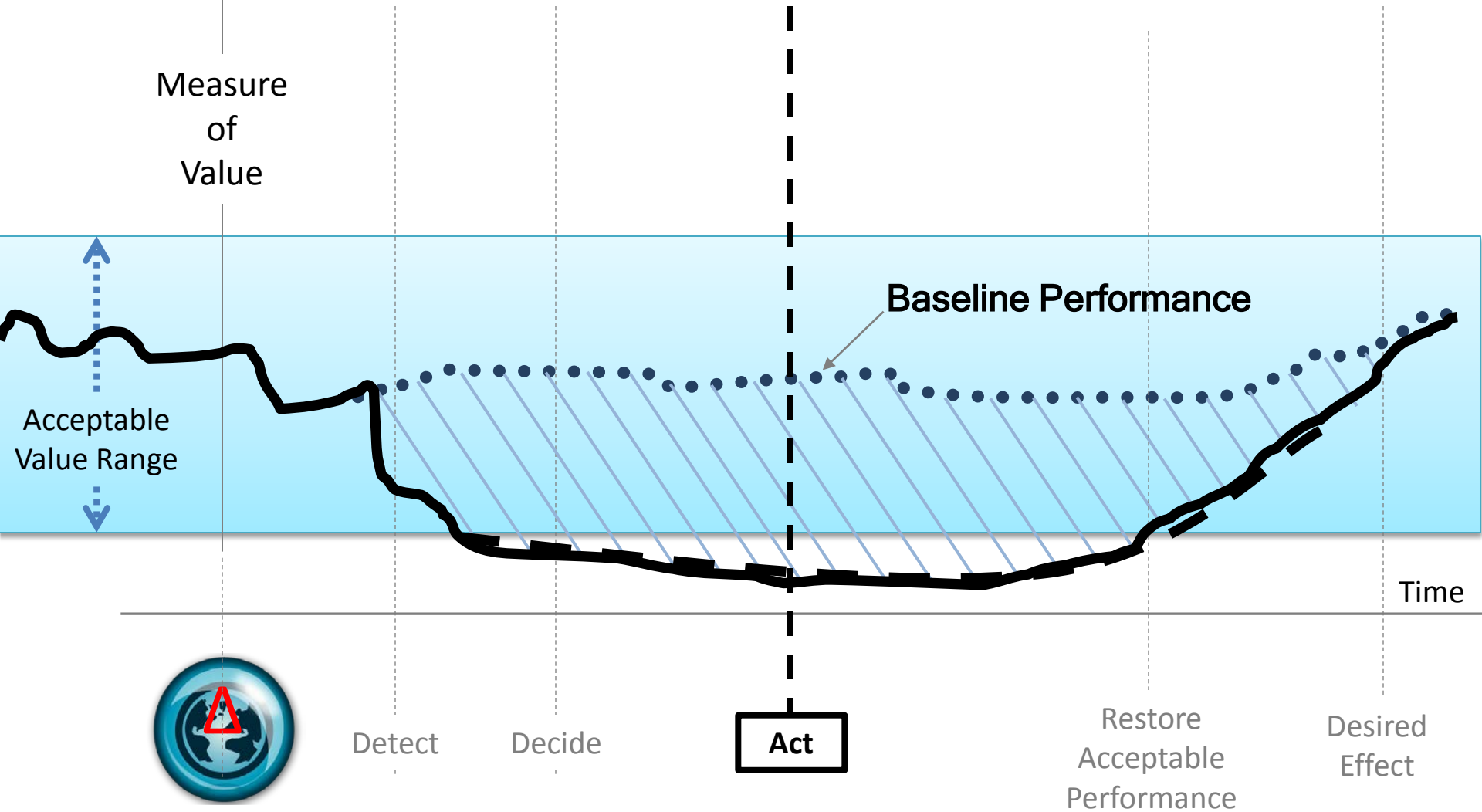
Source: Alberts, The Agility Advantage (2011)

Anatomy of Responsiveness
Illustrative Impact of Holding Action



Source: Alberts, The Agility Advantage (2011)

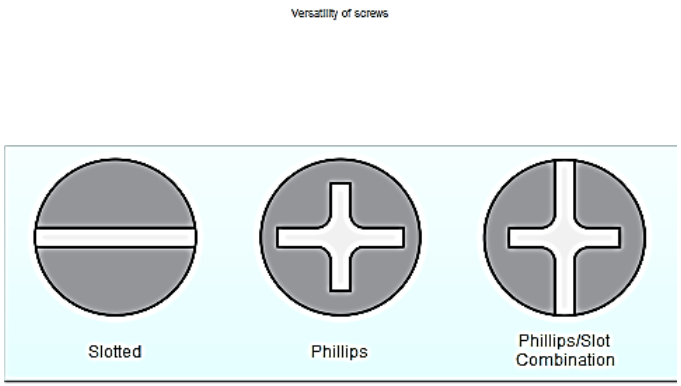
Anatomy of Responsiveness
Illustrative Impact of Anticipatory Response



Source: Alberts, The Agility Advantage (2011)

Versatility

- Versatility is the passive capability that enables an entity to maintain an acceptable level of performance without having to take action or change oneself.



Screw is able to successfully function under multiple circumstances (different screw drivers)

Flexibility

- *Flexibility* is having more than one way to achieve a desired result.
- Having options becomes important if the preferred way cannot be exercised, does not work given the circumstances, or becomes prohibitively costly.
- In theory, the more options one has, the more likely it is that one will have a good option available whatever the circumstances.
- As the number of options in one's tool kit increases, the marginal contribution of each additional option gets smaller (the law of diminishing returns).

Flexible Tool Kit

Resilience

- *Resilience* pertains to changes in circumstances that limit, damage or degrade entity performance.
- Being resilient involves an ability to maintain performance within acceptable bounds despite suffering damage.
- Resilience can be either passive or active or both
  - Being resilient may require that some action being taken (e.g. bring some offline capability on-line) or it may require no action be taken (e.g. existing redundancies provide the protection needed).
  - For example, an appropriately designed network can still provide acceptable services in the event a number of links goes down.

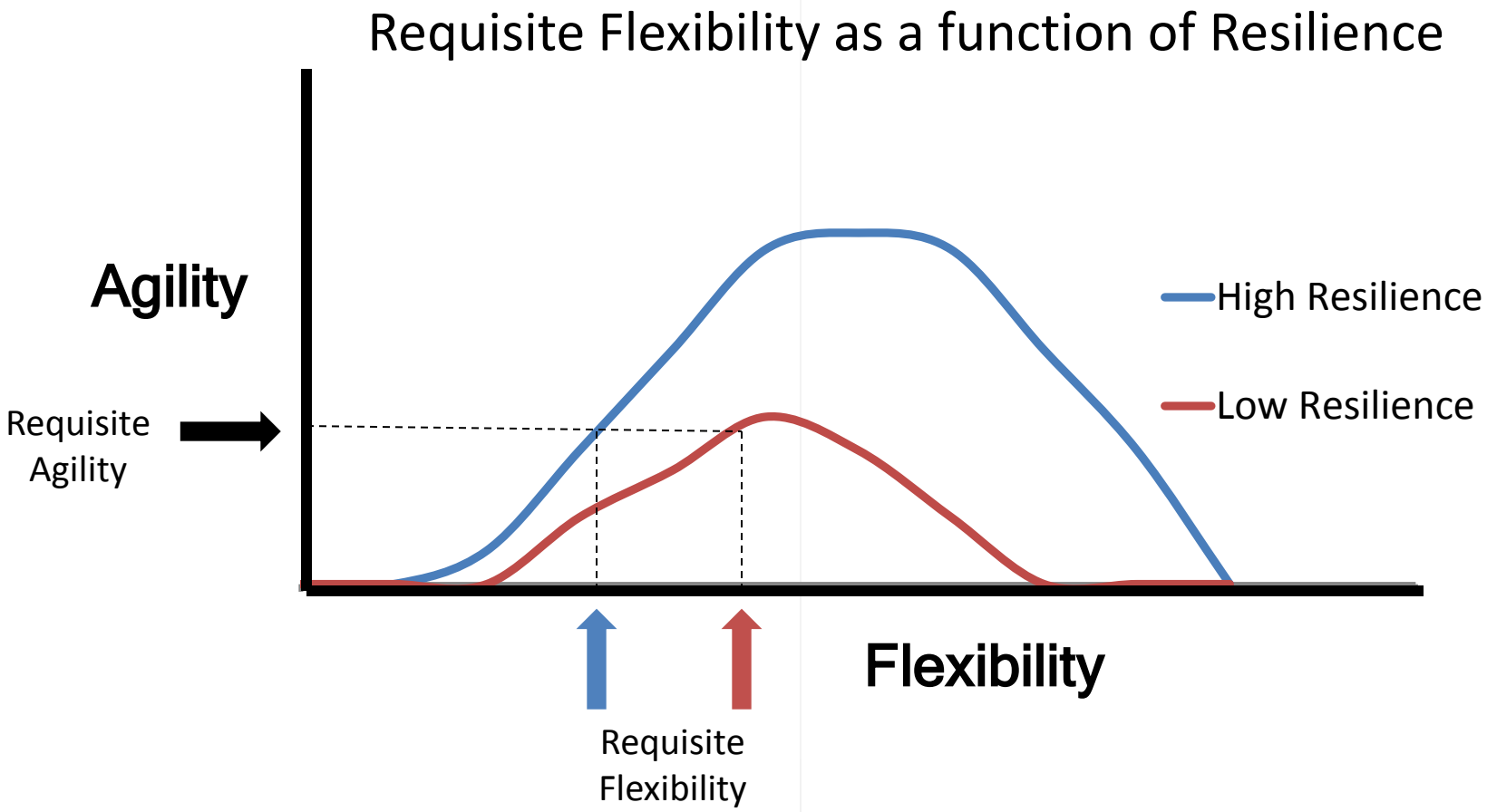
Adaptability

- *Adaptability* refers to making changes to self
- In this case, it is not what one does (choose an alternative course of action) that needs to change, but what one is and how one operates.
- Thus, *adaptability* involves changes to organization, policies, and/or processes.

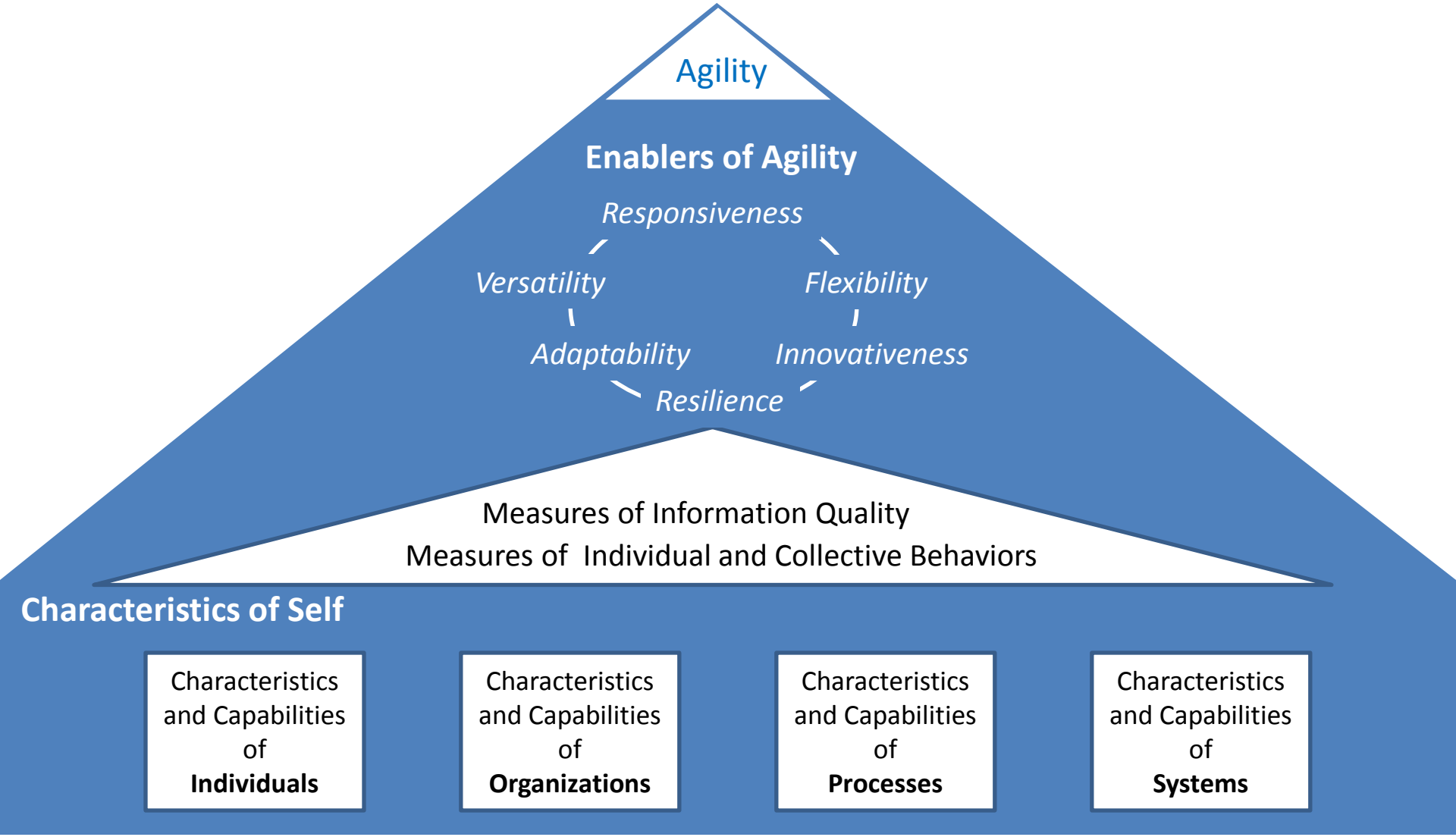
Innovativeness

- *Innovativeness* involves creating something new
  - e.g. a new way of accomplishing something when current practice does not provide options with adequate performance.
- While *flexibility* refers to having more than one choice, innovativeness adds new ways and means to the toolkit.
- Hence, *Innovativeness* enhances *Flexibility*

Interdependencies



Agility Value Chain



Agility Myths

Source: The Agility Advantage

- Agility would be nice to have, but we simply cannot afford it.
- We are already as agile as we can be.
- Agility means that you spend all your time preparing for something that will never occur.
- Agility is just another word for indecision.
- Agility will undermine traditional command and management authority.
- An agile force is a force that can not do anything well.
- It is not human nature to be agile; we are creatures of habit.
- Survival of the fittest determines what is important. If the institutions that have survived are not agile, then agility is not important.
- Agility is not a new idea. If we could be agile we would be.
- Decision makers demand quantifiable results. Agility is not quantifiable.
- Agility is all about speed of reaction, but sometimes speed is not as important as ensuring an appropriate response.

Discussion

Questions?

Comments?

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Command and Control
and its evolution

- What is Command and Control?
- Traditional Military Command and Control
- C2 Approach Space
- Networked Enabled Capability
- NATO NEC C2 Maturity Model
- Challenge of Complex Endeavors
- Where do we go from here?

Command and Control

- What is Command and Control?

- Why is Command and Control so hard?

Origins of C2

Commander as Head of State

Command and Control (1838)

"The Command of Armies and
the supreme Control of Operations"

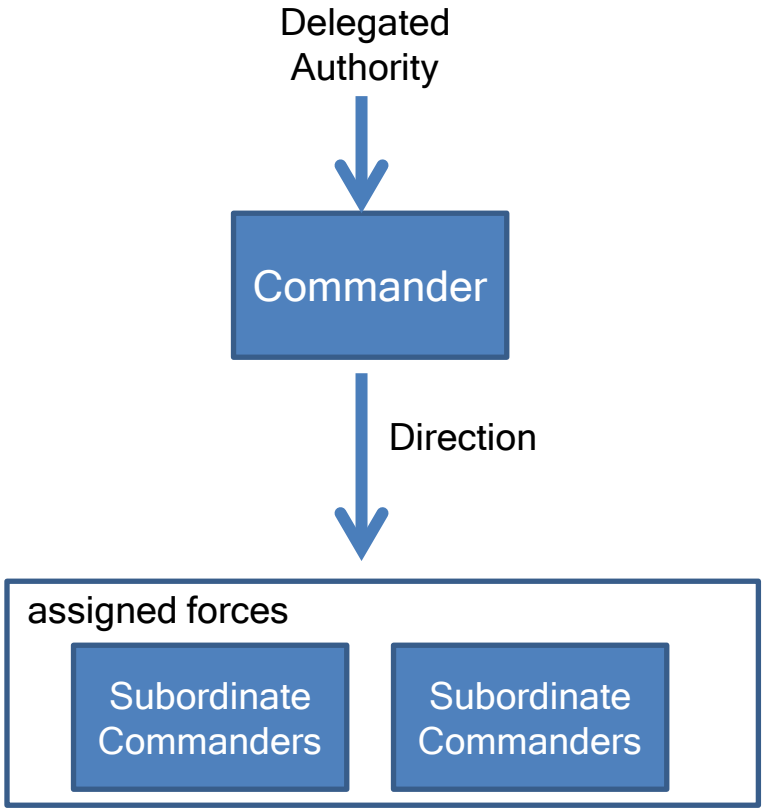
Command and Control (WWII)

"Take command and control of the forces"

Traditional Military Command and Control

Legal, Commander-centric Perspective

- The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. [1]
- Assumptions
  - Someone in charge
  - A single, unified chain of command
  - Hierarchical structure and information flows
- Measures of C2 Effectiveness
  - None specified, mission accomplishment implied
  - As a measure of C2 Effectiveness, mission accomplishment is problematic



1 Source: Joint Publication 1-02, *DOD Dictionary of Military and Associated Terms* 08 November 2010, as amended through 15 August 2012.

C2 Pragmatics

- C2 is not an end unto itself; rather it is a means (enabler) of value creation
- While even “perfect” command and control can not guarantee success, better command and control can improve the probability of success by better utilization and employment of resources (including information)
- Thus, a measure of C2 Quality that relates to the accomplishment of C2 functions (means) is needed

To Better Understand C2

- What C2 seeks to accomplish (objectives)
- How C2 seeks to accomplish its objectives (means)
- The metrics associated with its accomplishment C2 (quality)
- Different approaches to C2 (if any)
- When they are appropriate
- Assumptions, conditions, and constraints and when and how they apply

Problems with Definition of C2

- An Objective (mission accomplishment) is specified but it is for the Force, not what C2 needs to accomplish in order to enable the Force to achieve its objective
- Means are specified (authority and direction) but not completely
- No C2 quality metrics are specified
- Approaches to C2 are not addressed
- C2 Assumptions are implicit

Levels of C2

- C2 takes place simultaneously at many different levels
  - Inter-agency, Coalition
  - Institution (e.g. Department, Ministry)
  - Strategic, Operational, Tactical
- Approaches (as well as their success) can vary between and among levels
- Missions /tasks can vary greatly by type and scale
- C2 effectiveness depends upon the compatibility of the approaches adopted as well as their appropriateness

A Practical View of C2

- Focuses on the approach to C2 - how the functions could be performed, how well they are performed, and what difference it makes
- Thus, C2 is not every decision commanders make, but the choices that shape behaviors and information flows
- Therefore, C2 is about establishing the conditions under which sensemaking and execution take place
- Let's us readily see how advances in technology are and could change the way we think about and practice C2

C2 is about bring all available resources and information to bear

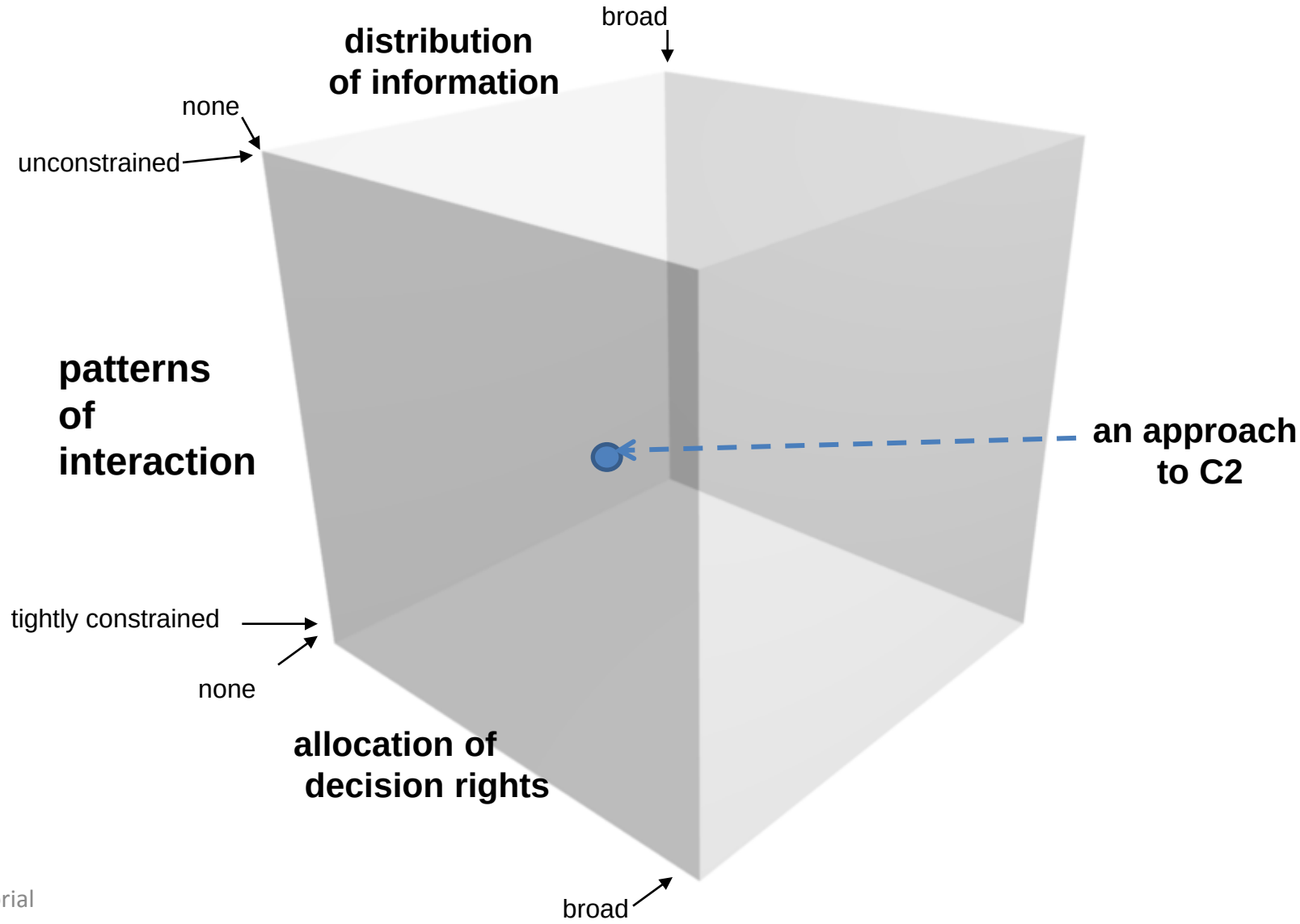
C2 Approach Space

- There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.

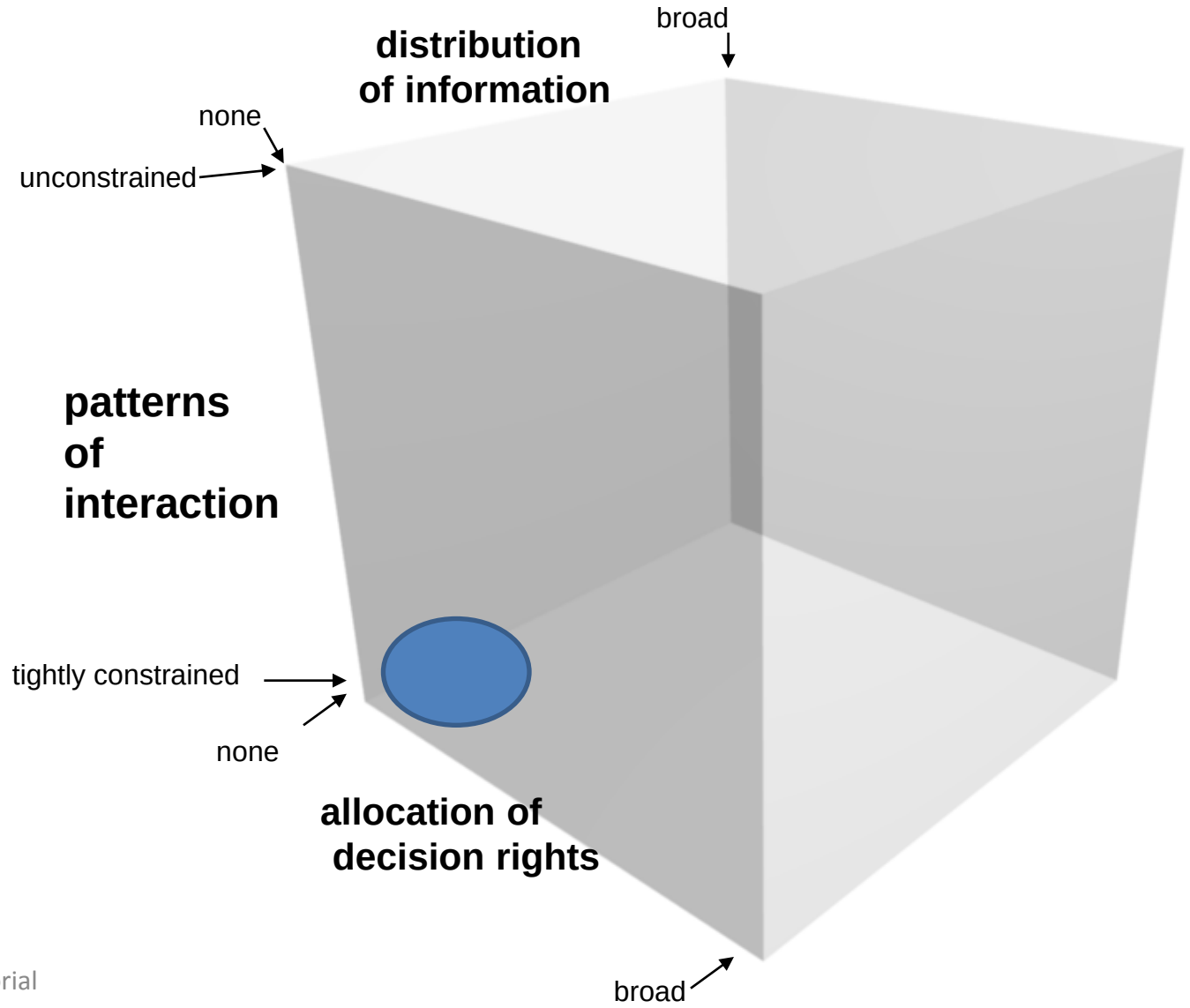
- Developing the "option space" for Command and Control requires that major differences between possible approaches are identified.
    - Centralized v. Decentralized
    - Fixed Vertical Stovepipes v. Dynamic Task Organized
    - Limited information dissemination (need to know) v. broad dissemination (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

Approaches to C2



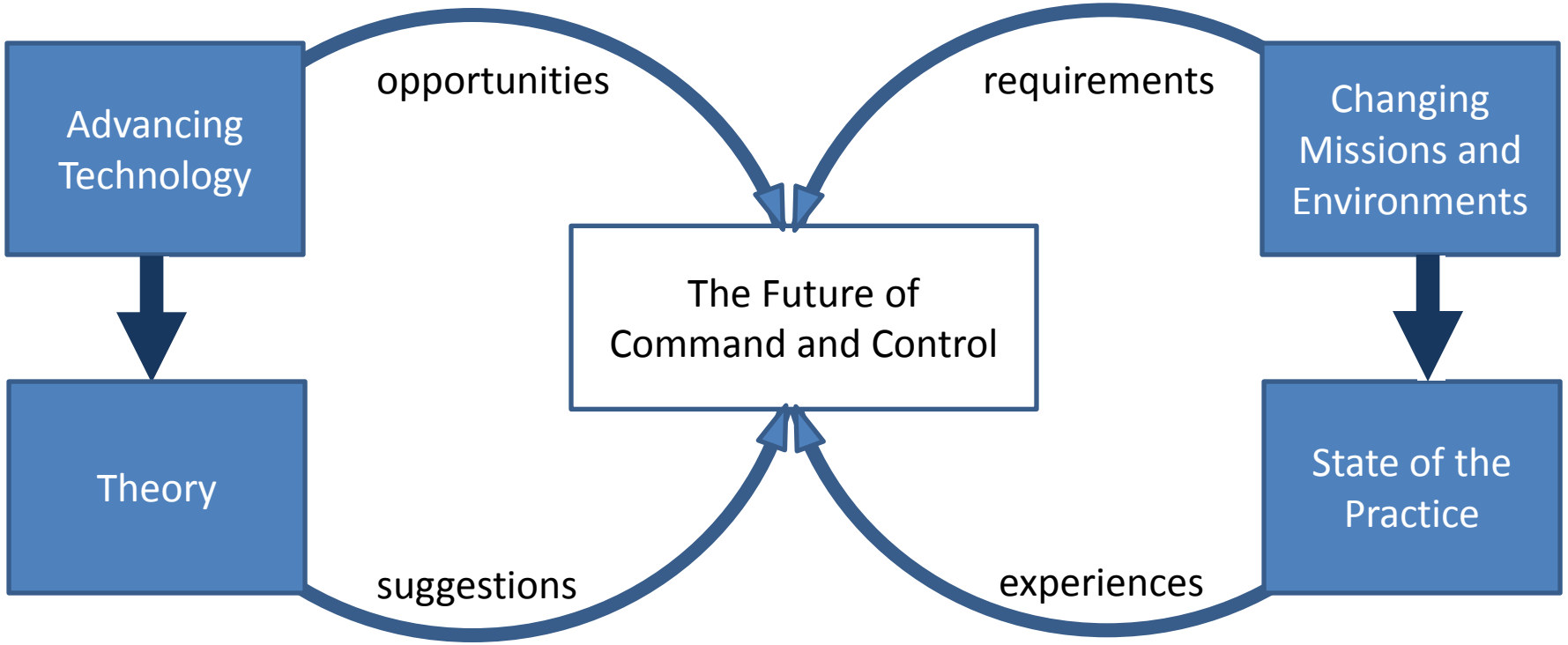
Traditional Military C2



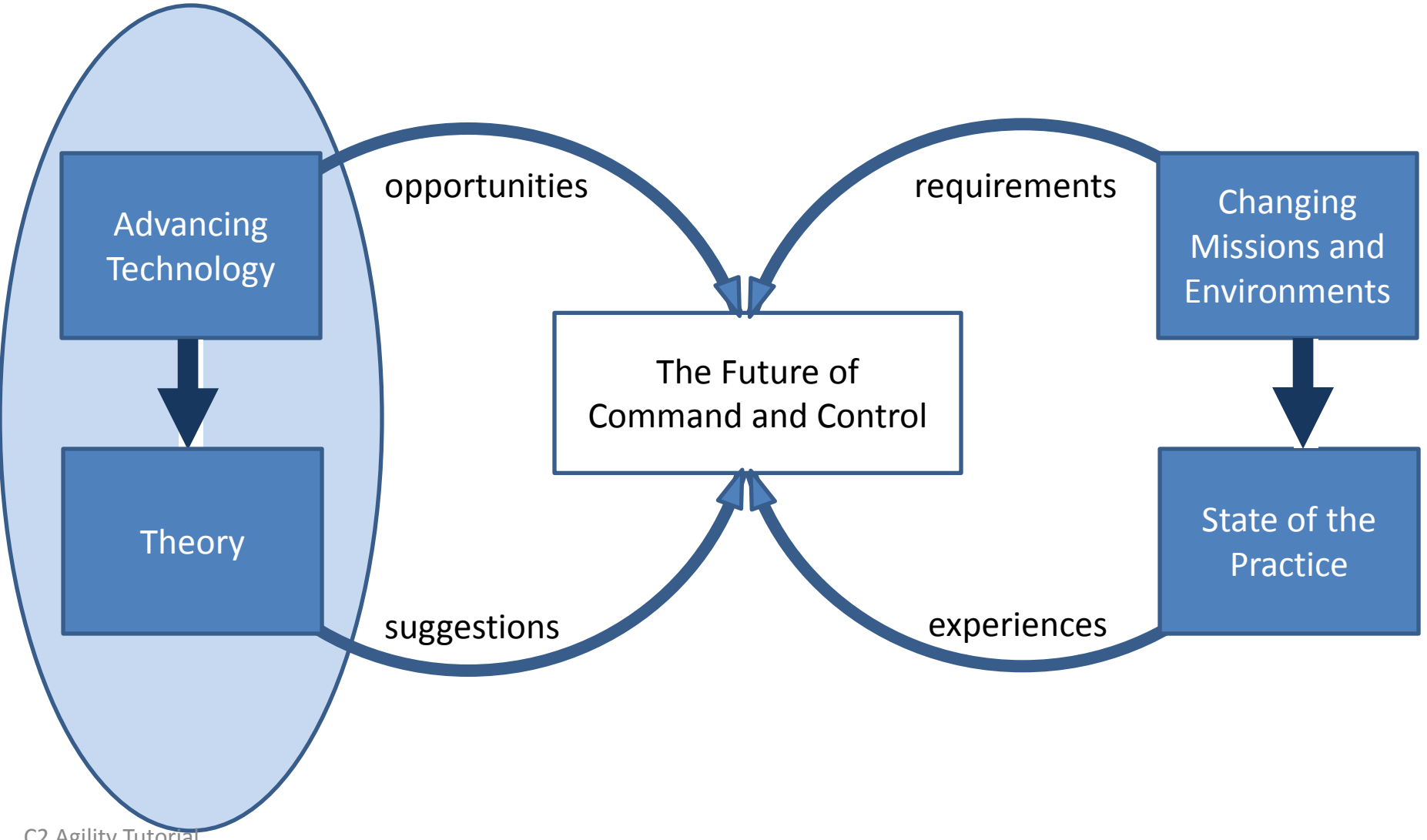
Questions

- Is the traditional approach to command and control appropriate for today's missions and circumstances?
- If, not, why not?
  - What changes are needed to the way we approach command and control?
  - What are the implications for doctrine, education, training, and systems ?

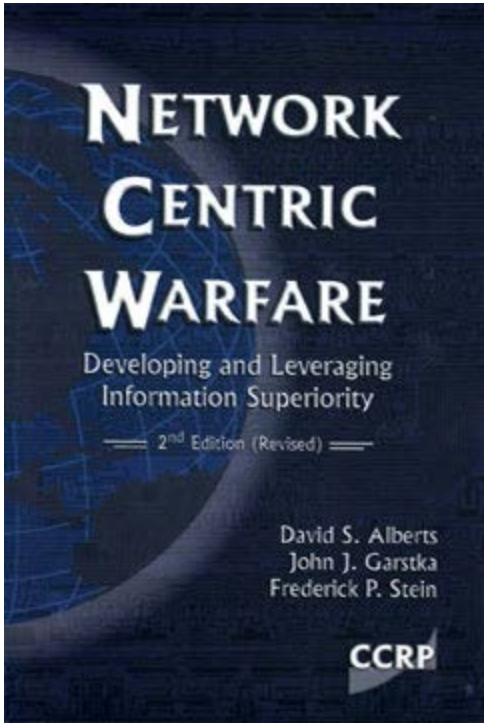
Drivers of Evolution



Drivers of Evolution



Information Age C2



Tenets of NCW

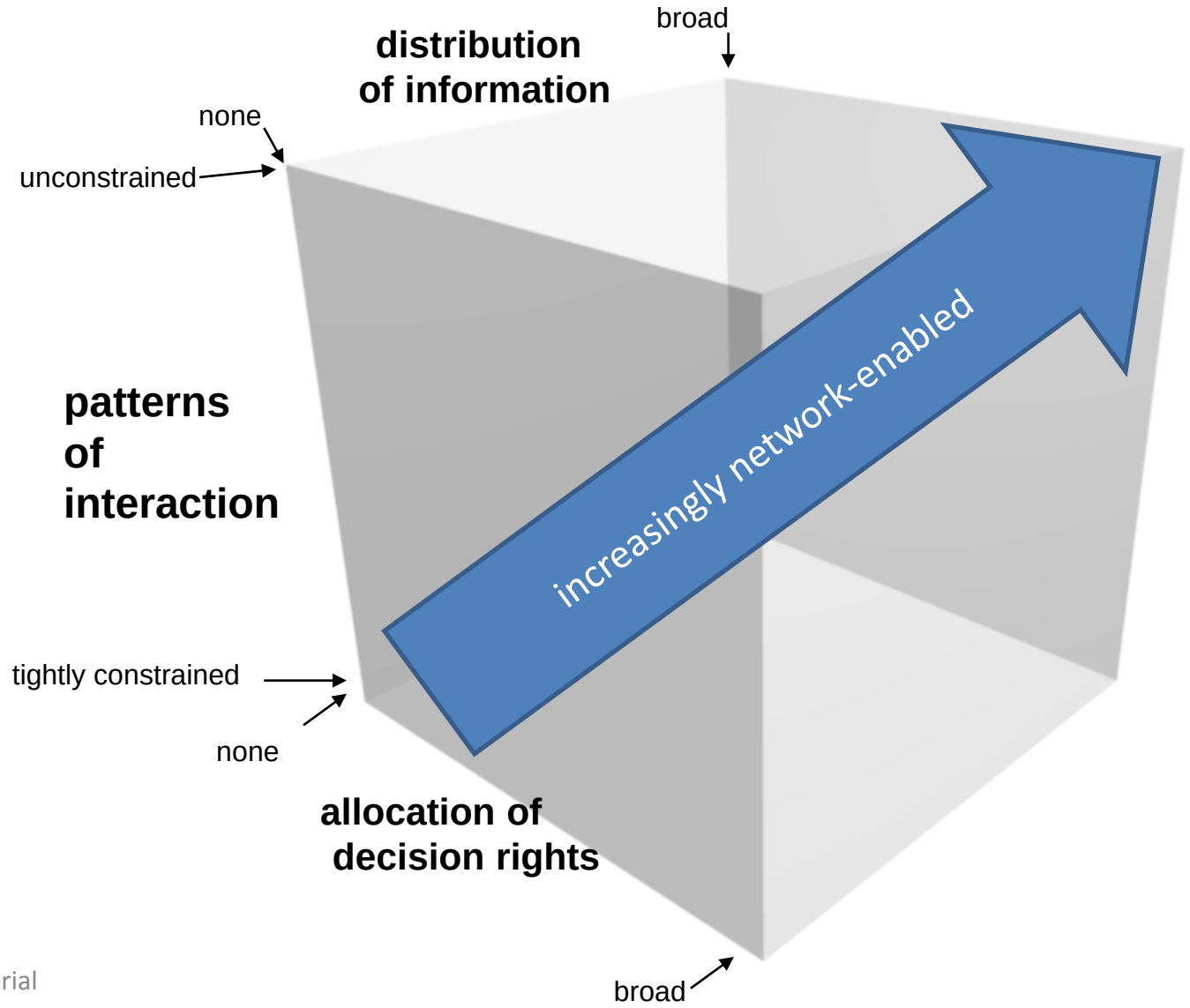
A *robustly networked force* **improves** *Information Sharing*

Information Sharing and *Collaboration* **enhances** *Quality of Information* and *Shared Situational Awareness*

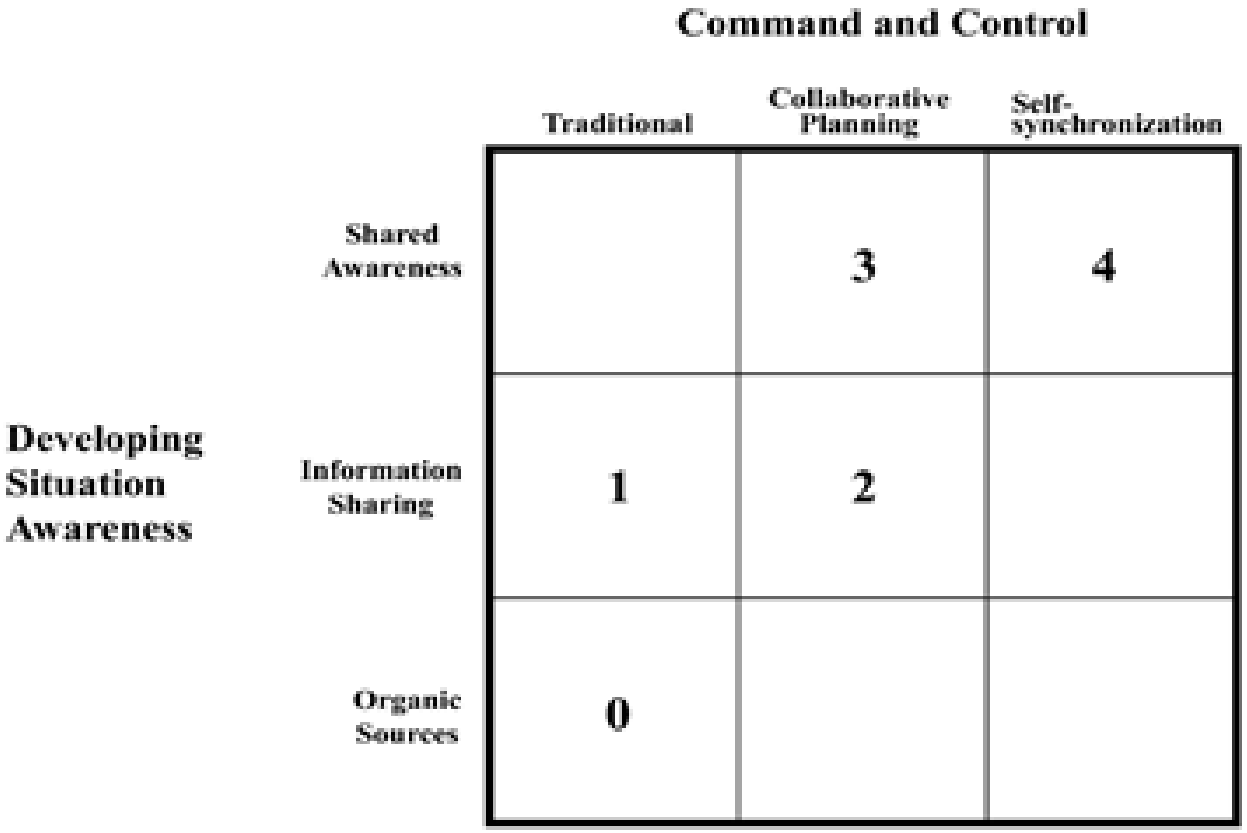
Shared situational awareness **enables** *Collaboration* and *Self-synchronization*

These, in turn, dramatically increase *mission effectiveness.*

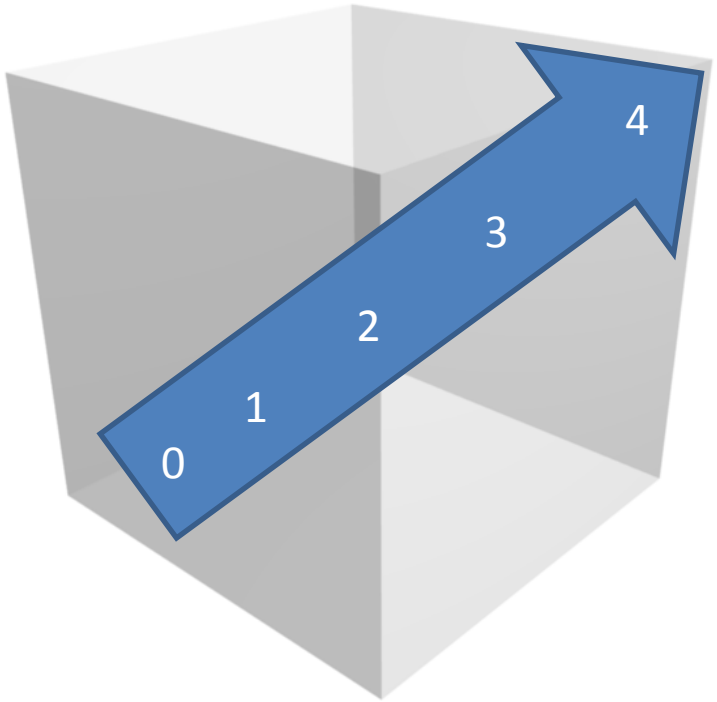
Network-enabled C2



Network Centric Maturity Model



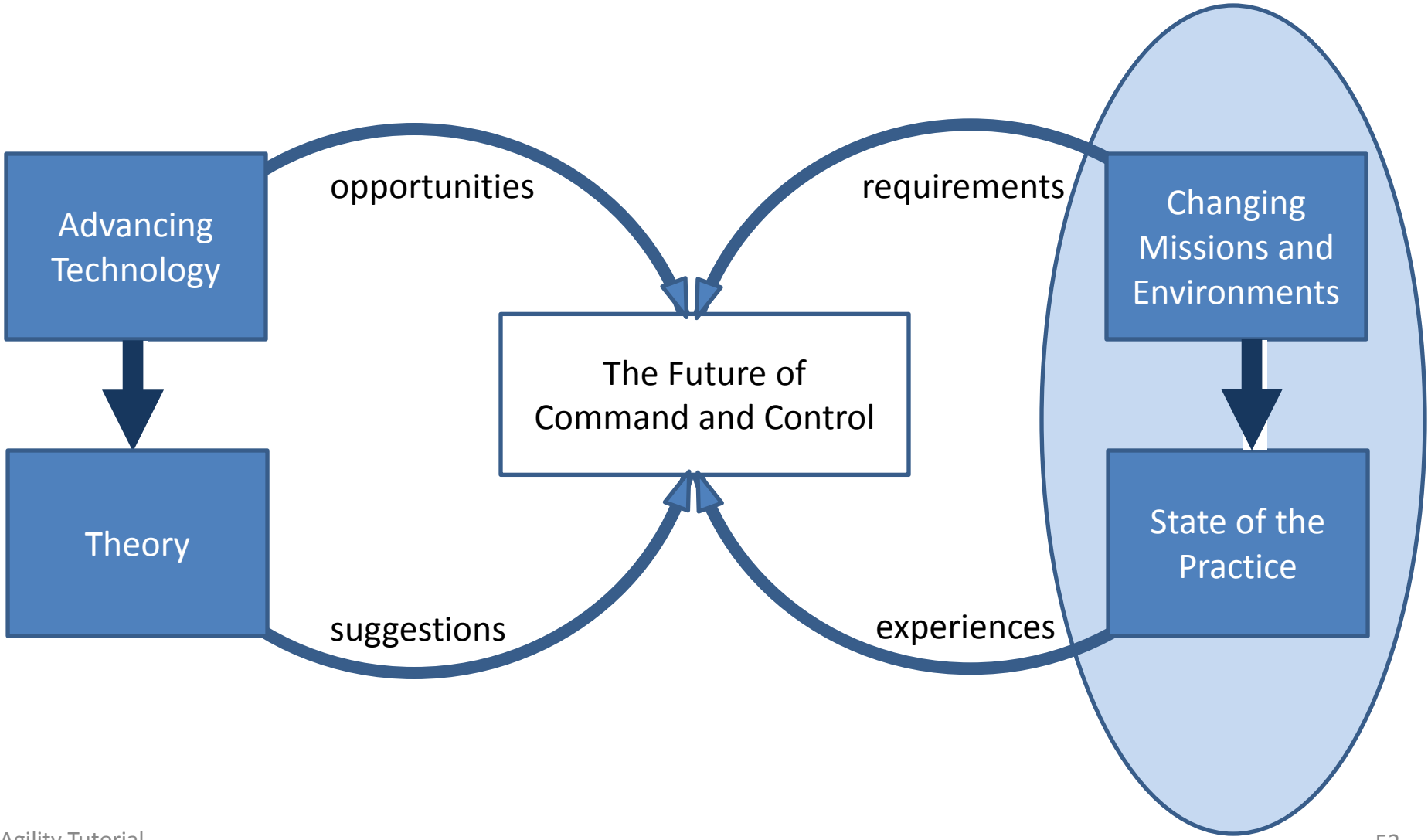
NEC2 Migration Path



Network Centric Maturity Model

Developing Situation Awareness	Command and Control: Traditional	Collaborative Planning	Self-synchronization
Shared Awareness		3	4
Information Sharing	1	2	
Organic Sources	0		

Drivers of Evolution



Challenges to Traditional C2 Assumptions
Complex Endeavors

- Complex Endeavors involve Complex Enterprises
- Entities will each have their own intent.
- The situation will be, in part, unfamiliar to all entities.
- There will be multiple planning processes.
- Critical information and expertise necessary to understand the situation will be spread among different organization.
- Actions, to be effective, will require developing synergies between and among entity actions.

Complex Endeavors call for command arrangements are more distributed and network-enabled

Challenges to Traditional C2 Assumptions

Unpredictability

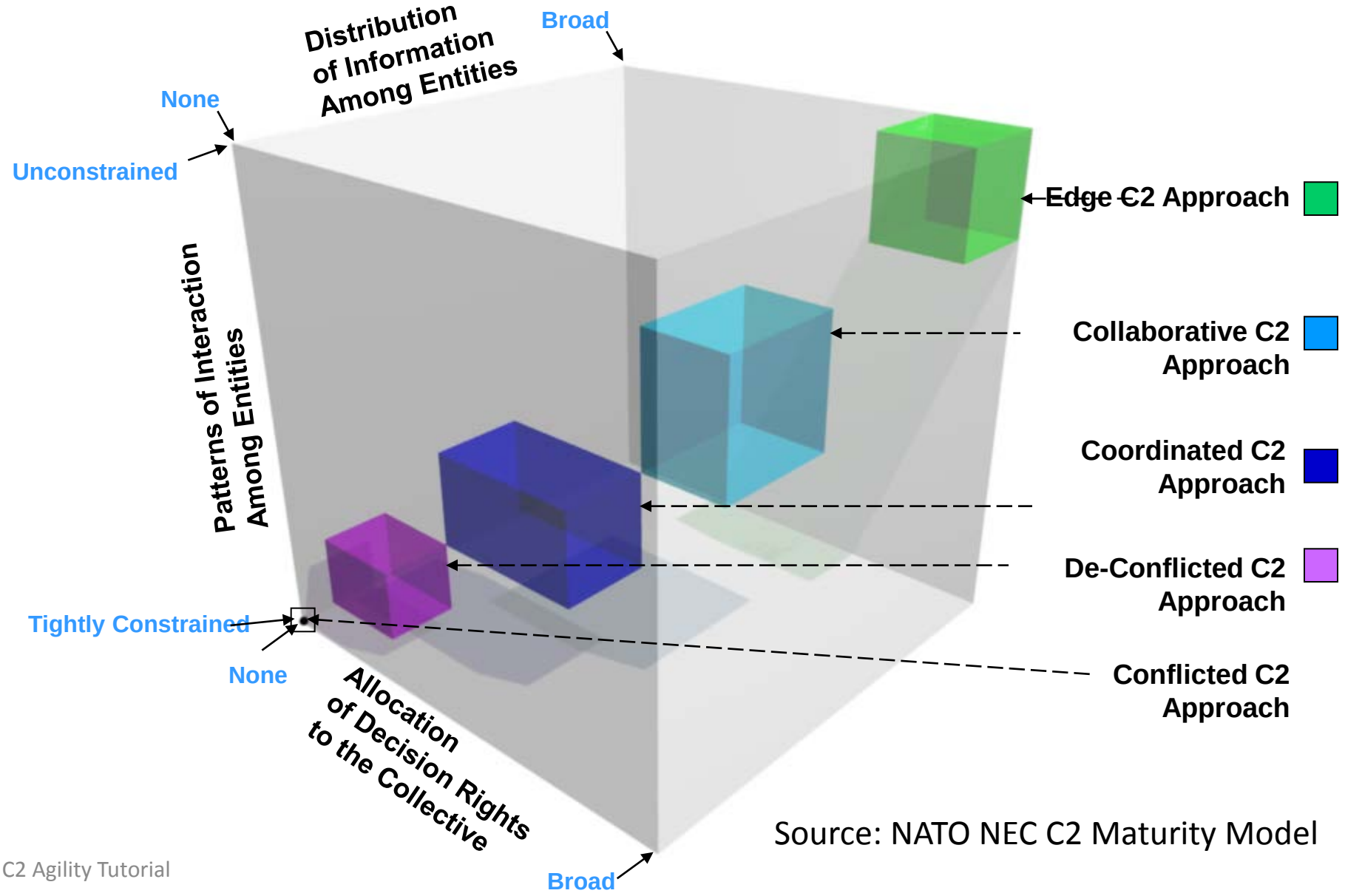
- Increased complexity will make the unexpected occur with greater frequency
- The effective lives of plans will be shorter – they may expire within the planning cycle.
- Critical information and expertise necessary to understand the situation will not be available
- Traditional approaches to decision making under uncertainty will be less applicable

The most appropriate response to increased complexity and the associated increases in uncertainty and risk is increasing C2 Agility

Assessment

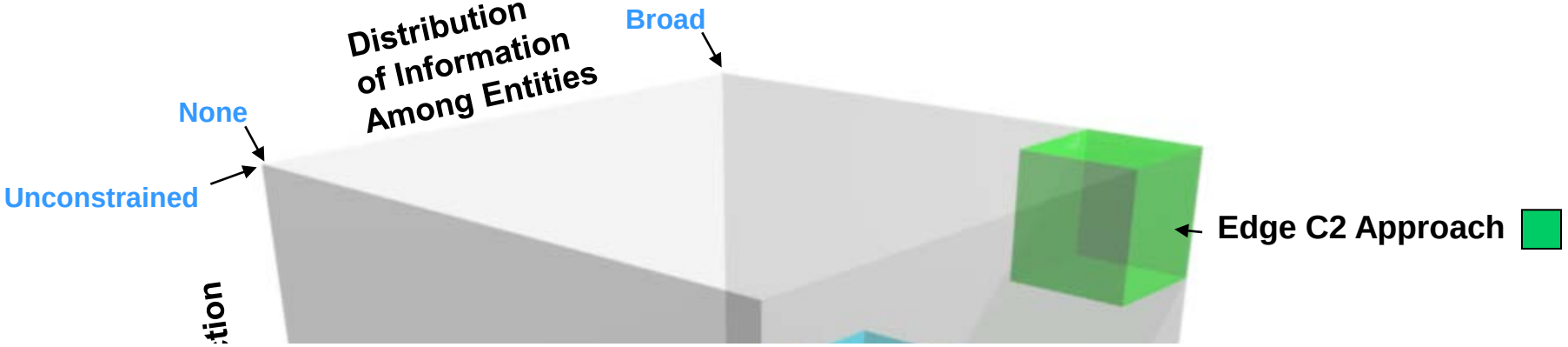
- Traditional approaches to Command and Control are increasingly unable to satisfy critical mission requirements
- The economics of Command and Control have changed significantly and continue to change at a rapid pace
- New Command and Control concepts and approaches are needed to satisfy mission challenges
- Fortunately, changes in the economics of communications and information are expanding the space of the possible
- Therefore, long held assumptions need to be revisited to allow access to this expanded space of C2 approach options

NATO NEC C2 Approaches



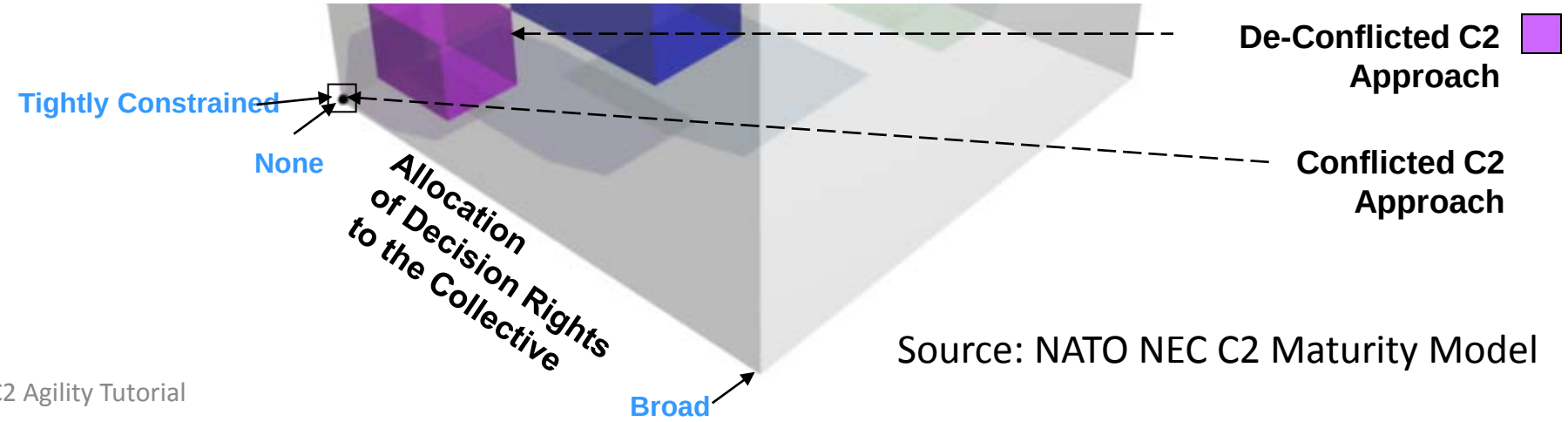
Source: NATO NEC C2 Maturity Model

NATO NEC C2 Approaches



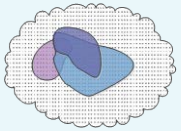
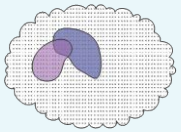
These approaches differ in the way they approach C2.

More networked enabled approaches are not necessarily more appropriate for a given mission and circumstance.



Source: NATO NEC C2 Maturity Model

NATO NEC C2 Maturity Levels

C2 Maturity Levels	Contents of C2 Toolkit	C2 Approach Decision Requirement	Transition Requirements	Region of the Endeavor Space where a collective is successful
Level 5	Edge C2 Collaborative C2 Coordinated C2 De-Conflicted C2	Emergent	Edge C2 Collaborative C2 Coordinated C2 De-Conflicted C2	
Level 4	Collaborative C2 Coordinated C2 De-Conflicted C2	Recognize 3 situations and match to appropriate C2 approach	Collaborative C2 Coordinated C2 De-Conflicted C2	
Level 3	Coordinated C2 De-Conflicted C2	Recognize 2 situations and match to appropriate C2 approach	Coordinated C2 De-Conflicted C2	
Level 2	De-Conflicted C2	N/A	None	
Level 1	Conflicted C2	N/A	None	

Adapted from the Alberts, D. S. (2011). Agility Advantage, CCRP

Conflicted De-Conflicted Coordinated Collaborative Edge

Questions

- Is the traditional approach to command and control appropriate for today's missions and circumstances?
  - *For some, but not for all missions and circumstances*
- If, not, why not? … what changes are needed?
  - *More networked-enabled C2 Approaches (NEC2)*
  - *Improved C2 Maturity*

Need for Agile C2

- There are *many ways* to accomplish the functions associated with Command and Control
- No one approach to accomplishing the functions associated with command and control 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 appropriately employ more than one approach

Discussion

Questions?

Comments?

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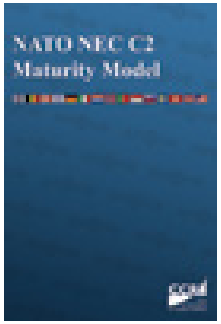
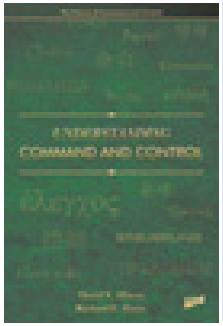
Origins of C2 Agility Theory

Agile C2 (2011)
The Agility Advantage



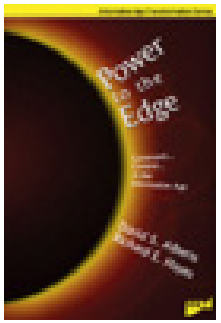
C2 Maturity Levels (2010)
NATO NEC C2 Maturity Model

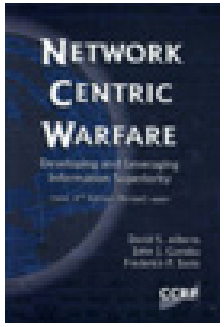
C2 Approach Space (2006)
Understanding Command and Control



NEC C2 Conceptual Reference Model (2006)
NATO SAS-050

NEC2 – Edge Approach(2003)
Power to the Edge

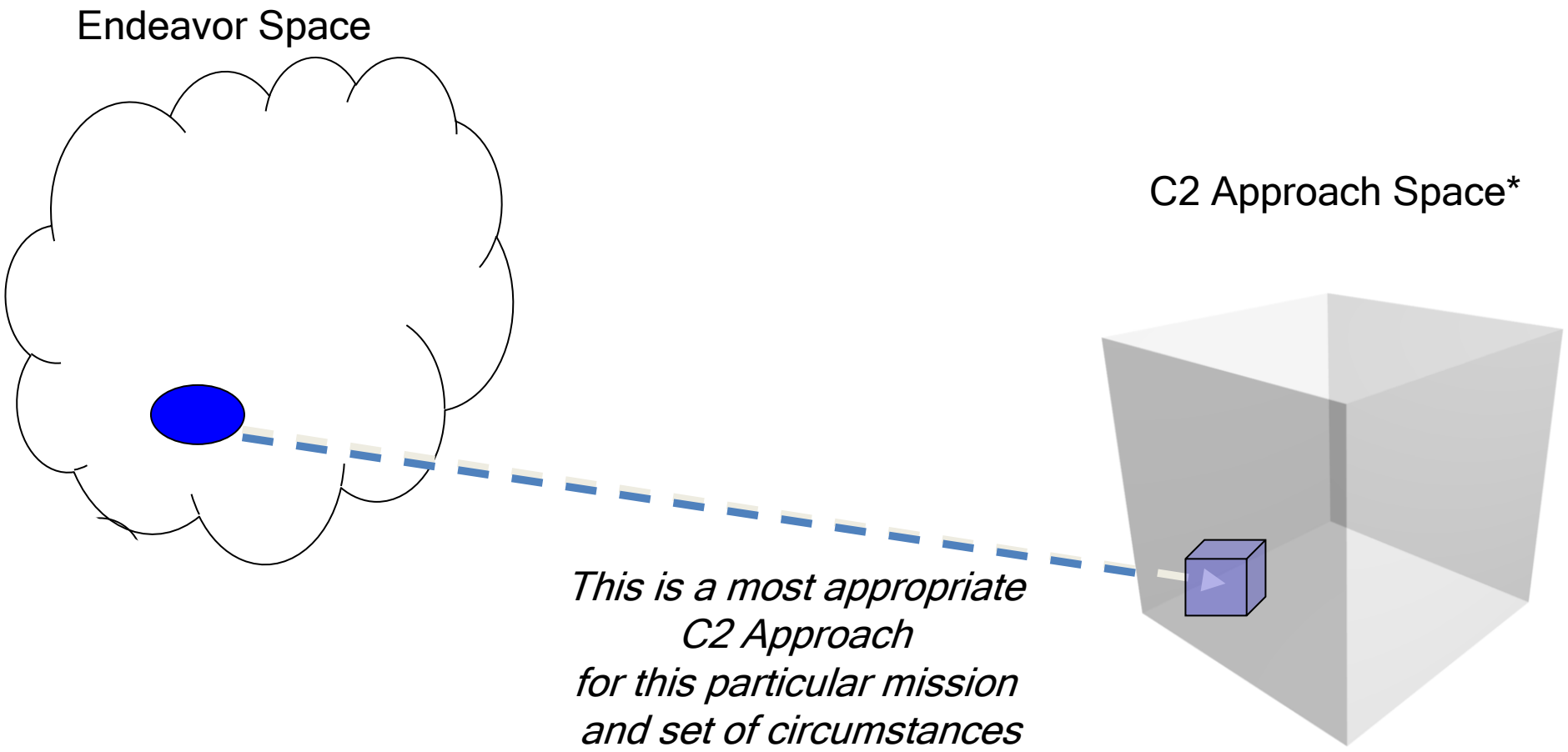




Network Centric Warfare
Tenets / Value Chain (1999)
Network Centric Warfare

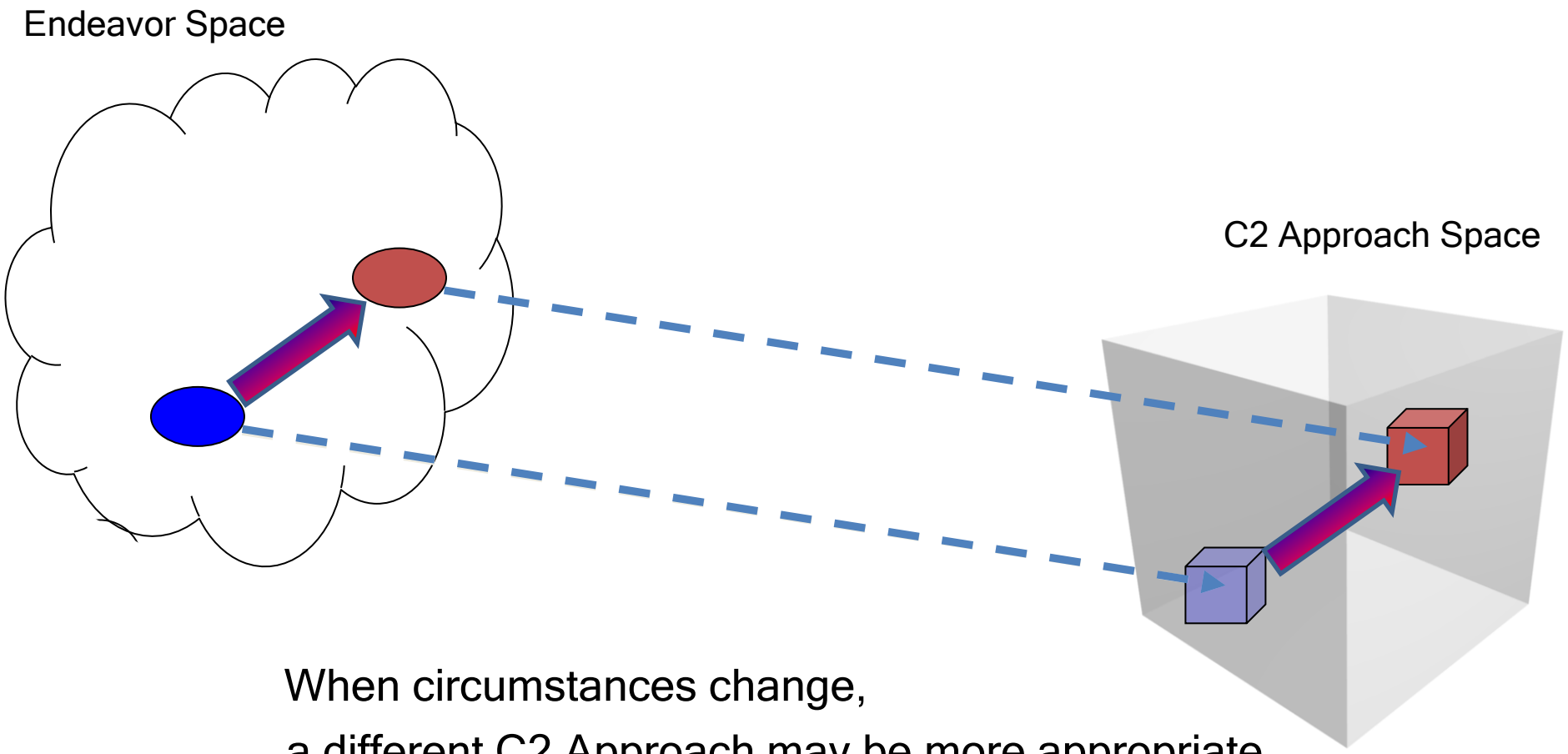
C2 Agility

Step 1: Adopt the Appropriate Approach

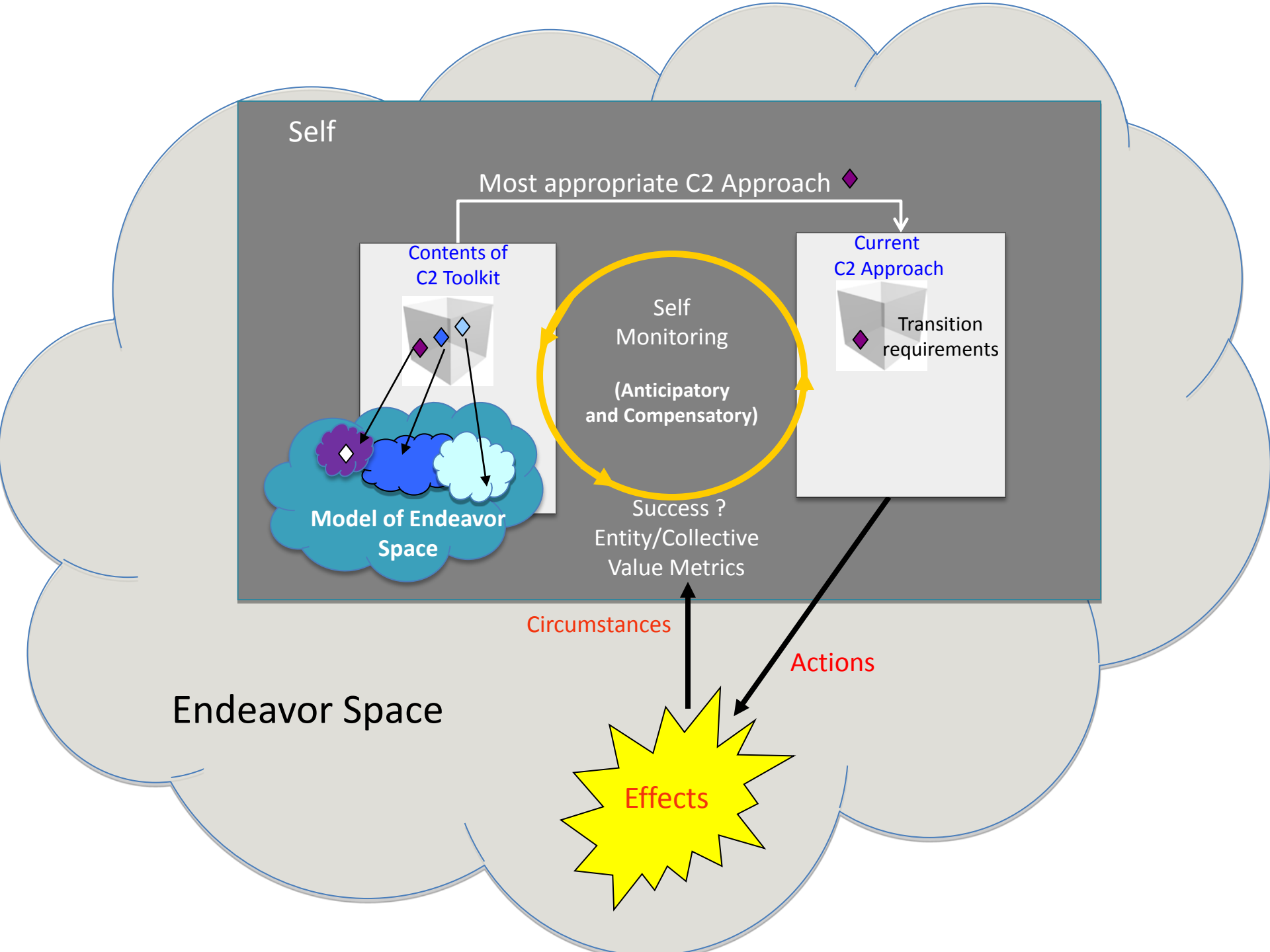


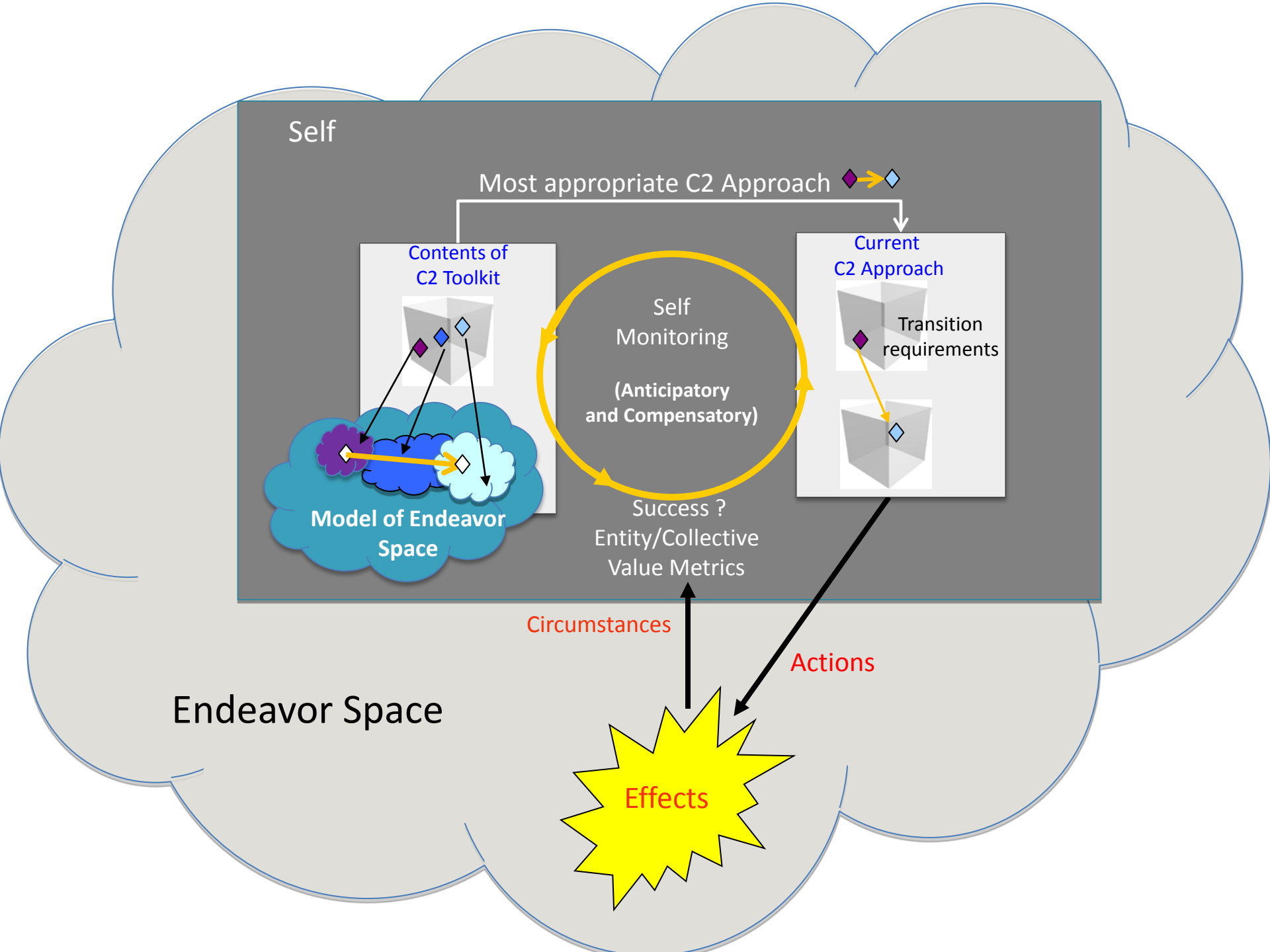
C2 Agility

Step 2: Adapt C2 Approach as Circumstances Change



When circumstances change,
a different C2 Approach may be more appropriate.


Self
Most appropriate C2 Approach
Contents of
C2 Toolkit
Current
C2 Approach
Transition
requirements
Self
Monitoring
(Anticipatory
and Compensatory)
Model of Endeavor
Space
Success ?
Entity/Collective
Value Metrics
Circumstances
Actions
Endeavor Space
Effects


Self
Most appropriate C2 Approach
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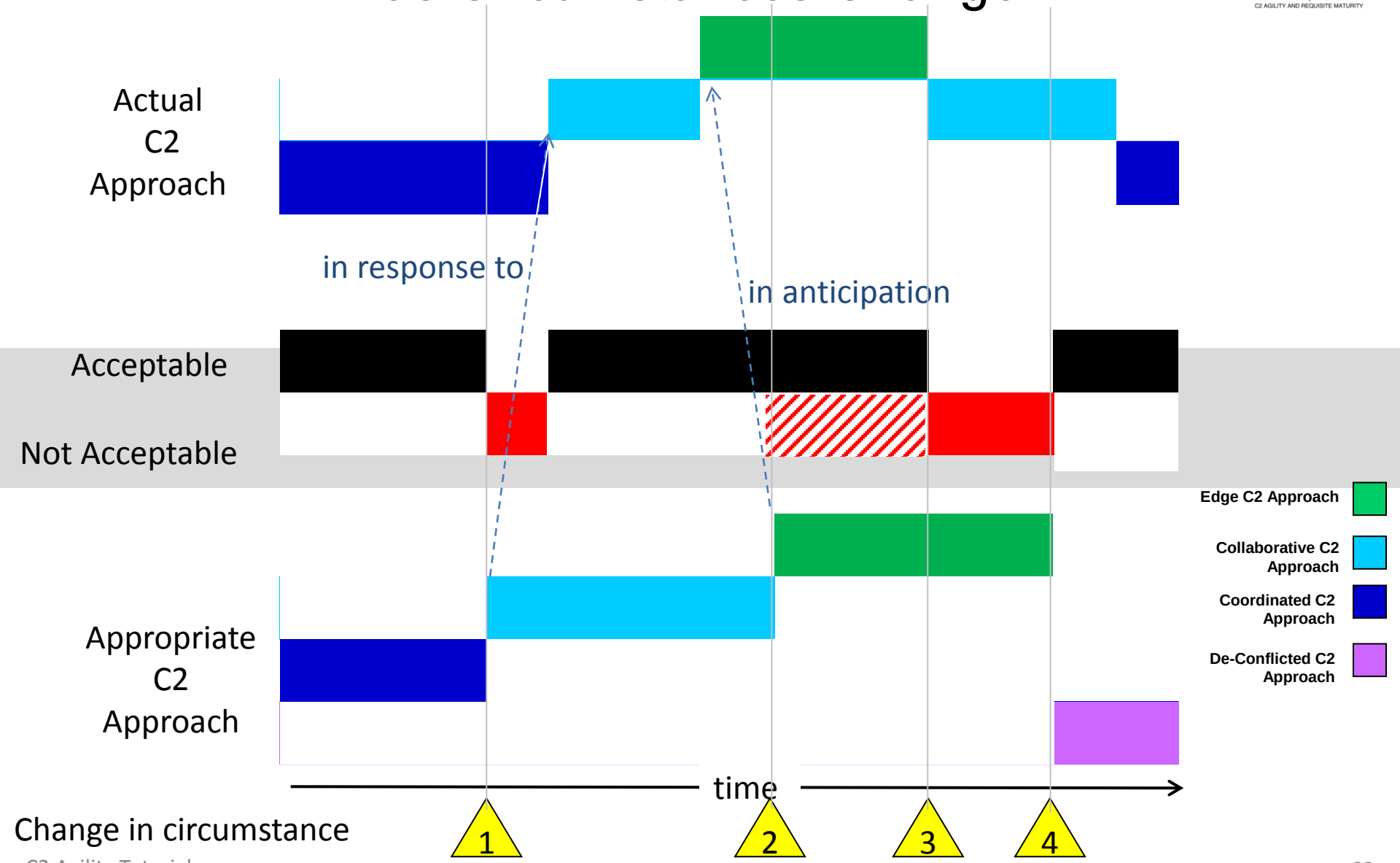
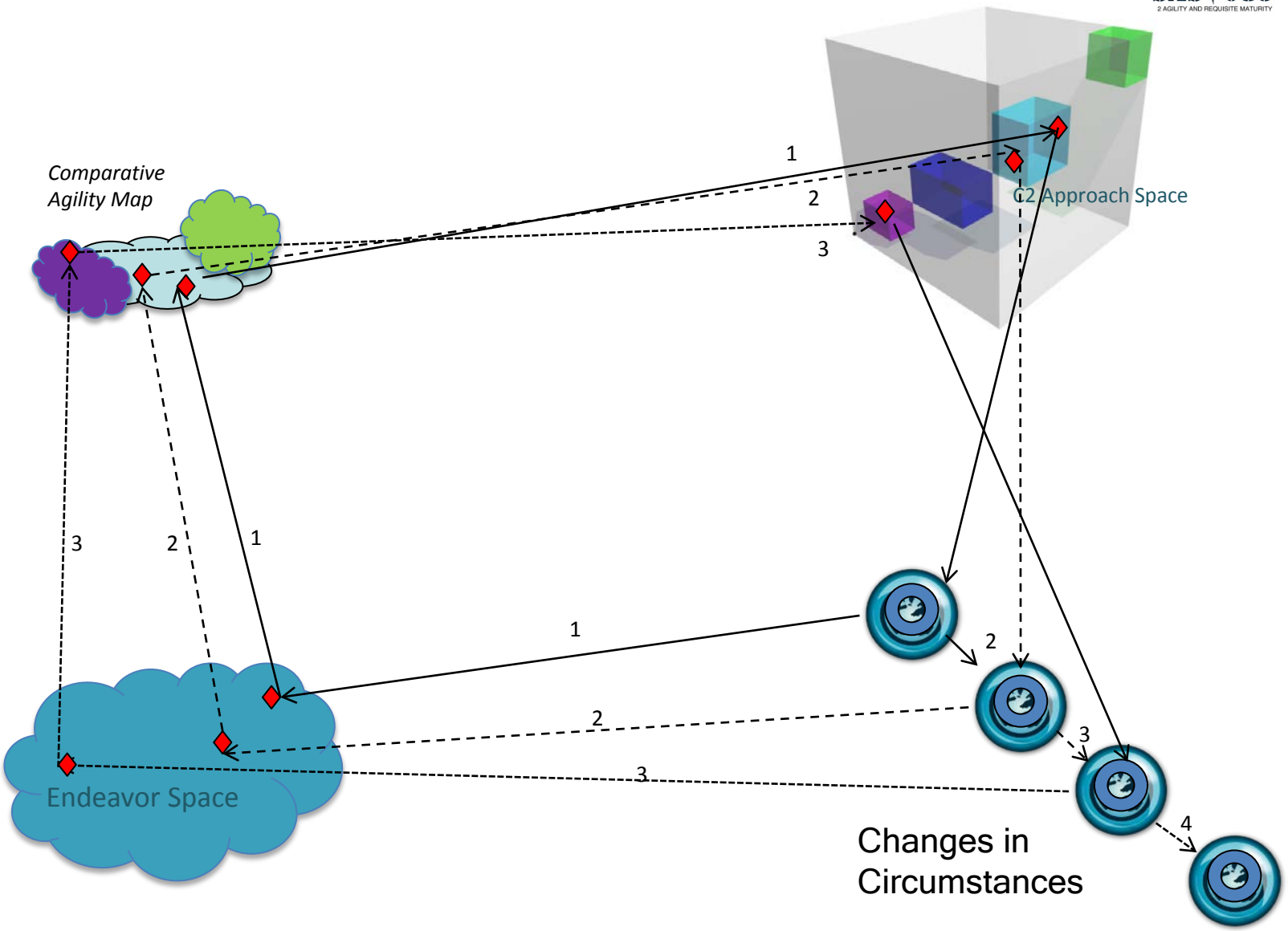
Self
Monitoring
(Anticipatory
and Compensatory)
Model of Endeavor
Space
Success ?
Entity/Collective
Value Metrics
Circumstances
Actions
Endeavor Space
Effects

Maintaining an Appropriate C2 Approach as Circumstances Change

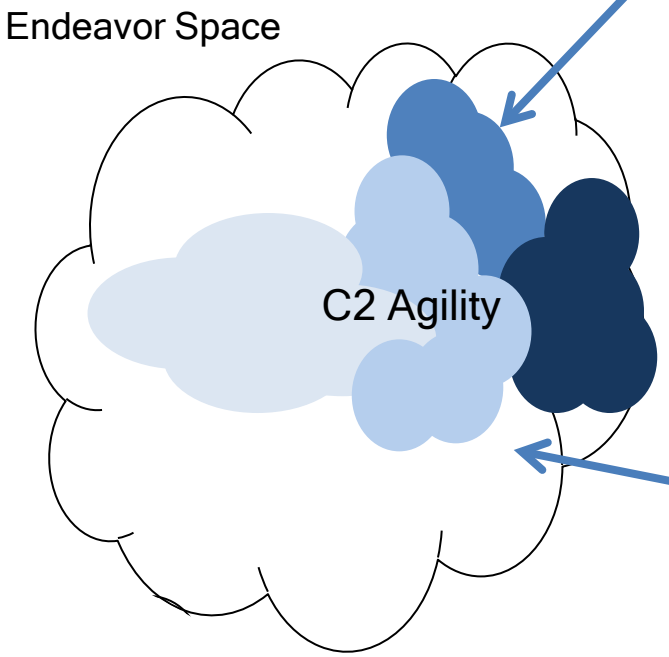


Dynamics of C2 Agility



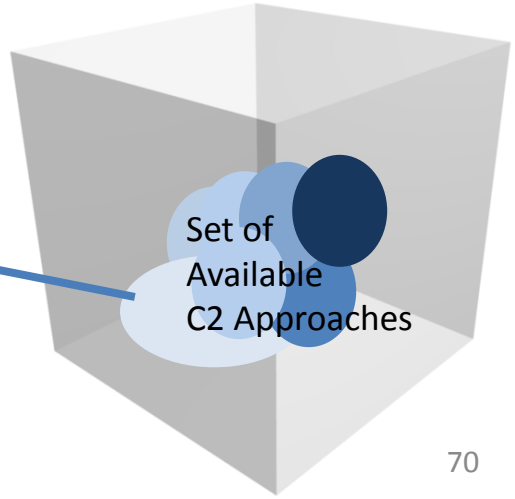
C2 Agility

- C2 Agility = f (C2 Approach Agility, C2 Maneuver Agility)

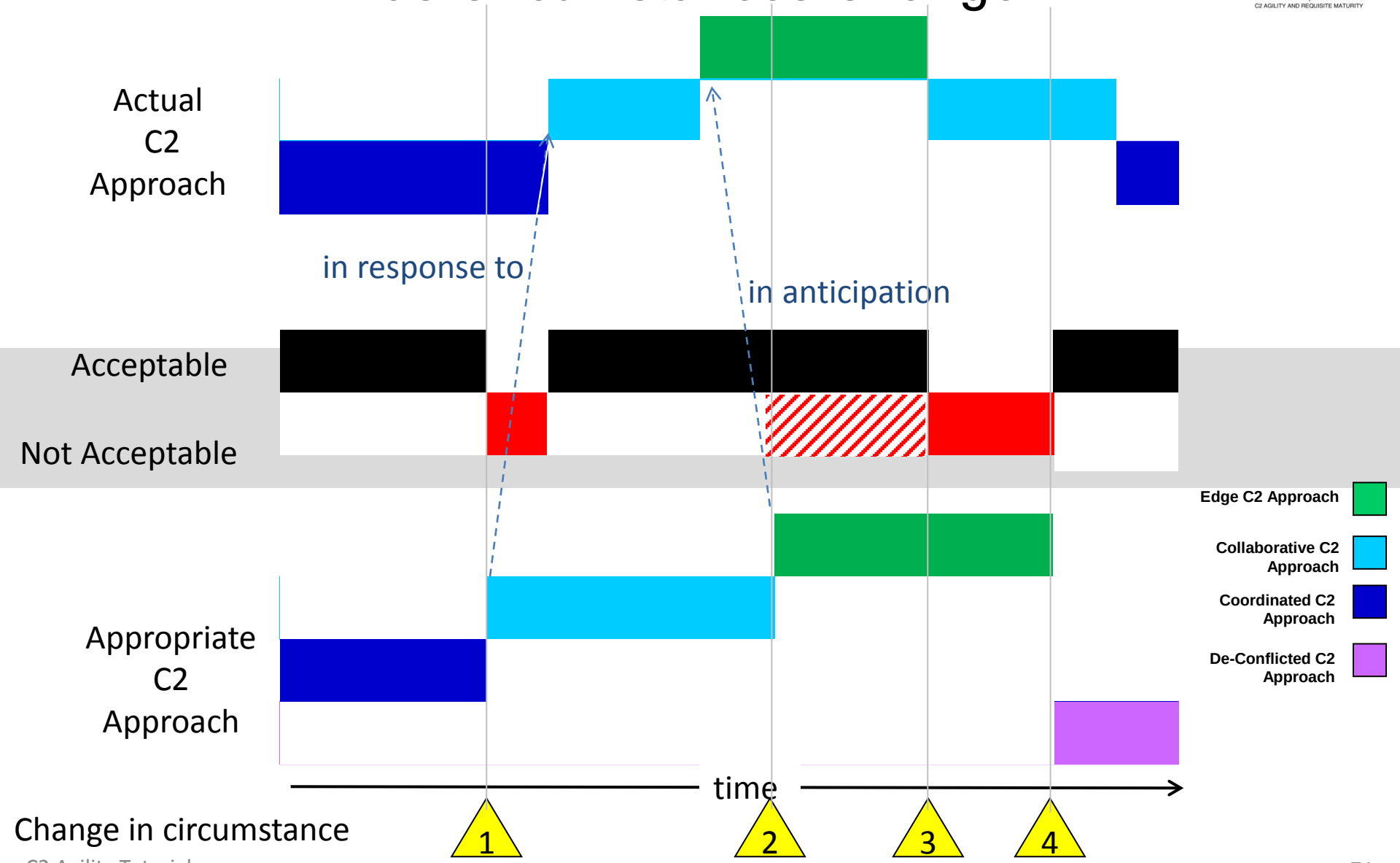


C2 Approach Agility is the area of the region in the Endeavor Space where an entity can operate successfully by employing a given approach to C2

C2 Maneuver Agility is the ability to recognize the C2 approach appropriate for the circumstances and transition to this approach in a timely manner. It is a function of the set of C2 Approaches available to the entity.



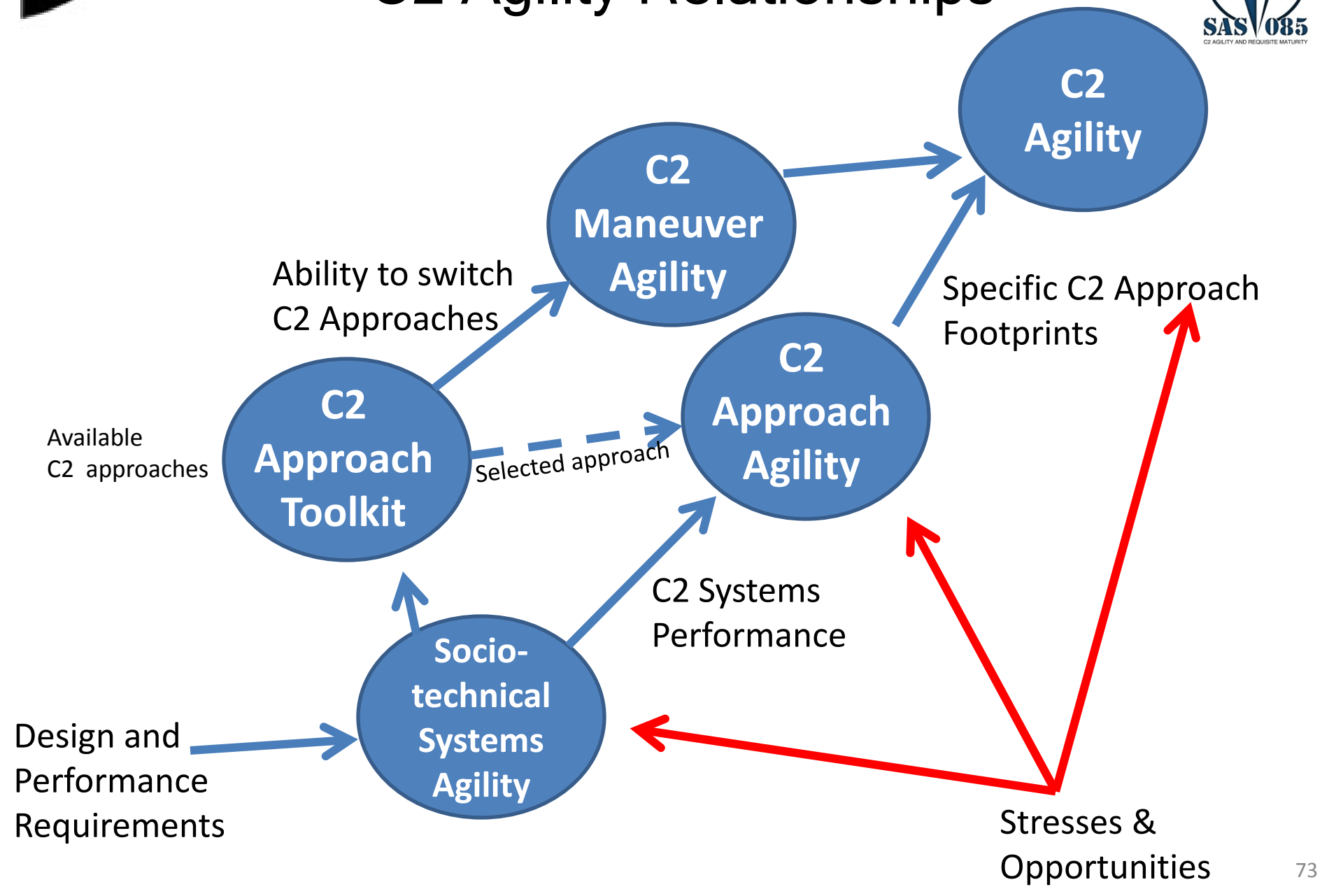
Maintaining an Appropriate C2 Approach as Circumstances Change



Traditional v Agile C2

	Traditional C2	Agile C2
Approach	one way	set of options
Decision Rights	limited delegation of decision rights	as appropriate
Interactions	prescribed interactions	tailored
Information Dissemination	limited – need to know	access as appropriate - need to share
System Requirements	point to point support established processes	network support emergent processes

C2 Agility Relationships



Discussion

Questions?

Comments?

Agenda

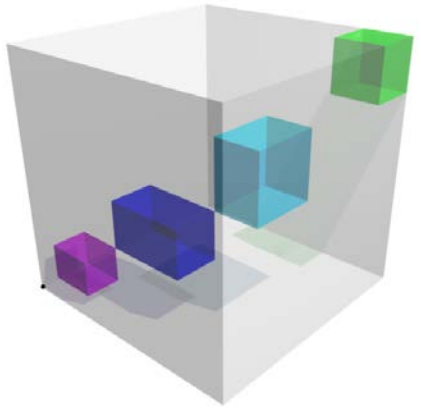
- Objectives
- Basics of Agility
- Evolution of Command and Control
- C2 Agility
- C2 Agility Hypotheses
- Validation
- Case Studies
- Campaign of Experimentation
- Summary of Findings, Conclusions, and Way Ahead

What is an Hypothesis?

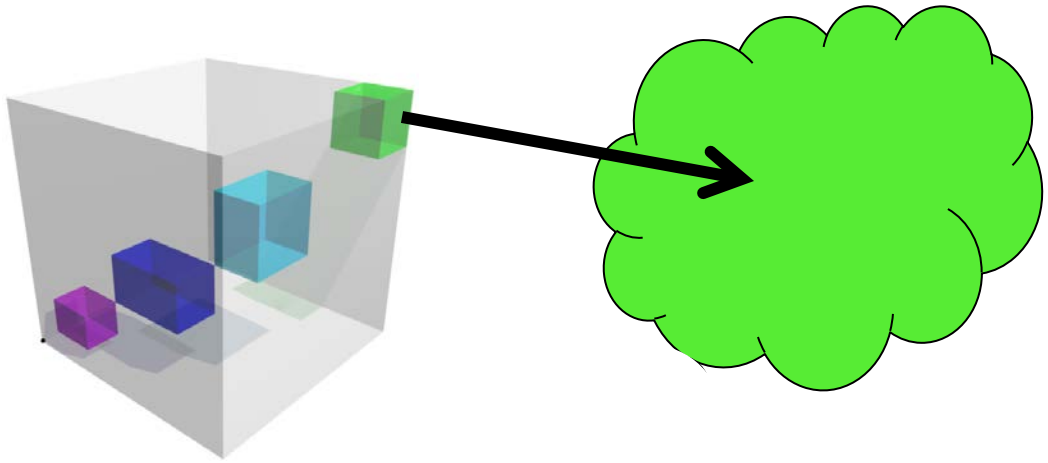
- A hypothesis is a clear statement articulating a plausible candidate explanation for observations. It should be constructed in such a way as to allow gathering of data that can be used to either accept the null hypothesis or reject the null in favour of the alternative hypothesis
- The case studies took a subjective qualitative approach when considering the acceptance or rejection of the null hypothesis
- The experiments took an objective quantitative approach when considering the acceptance or rejection of the null hypothesis
- Note: In this presentation only the alternative hypotheses are presented. The null hypotheses are implicit.

C2 Agility Hypotheses

H1: Each C2 Approach is located in a distinct region of the C2 Approach Space

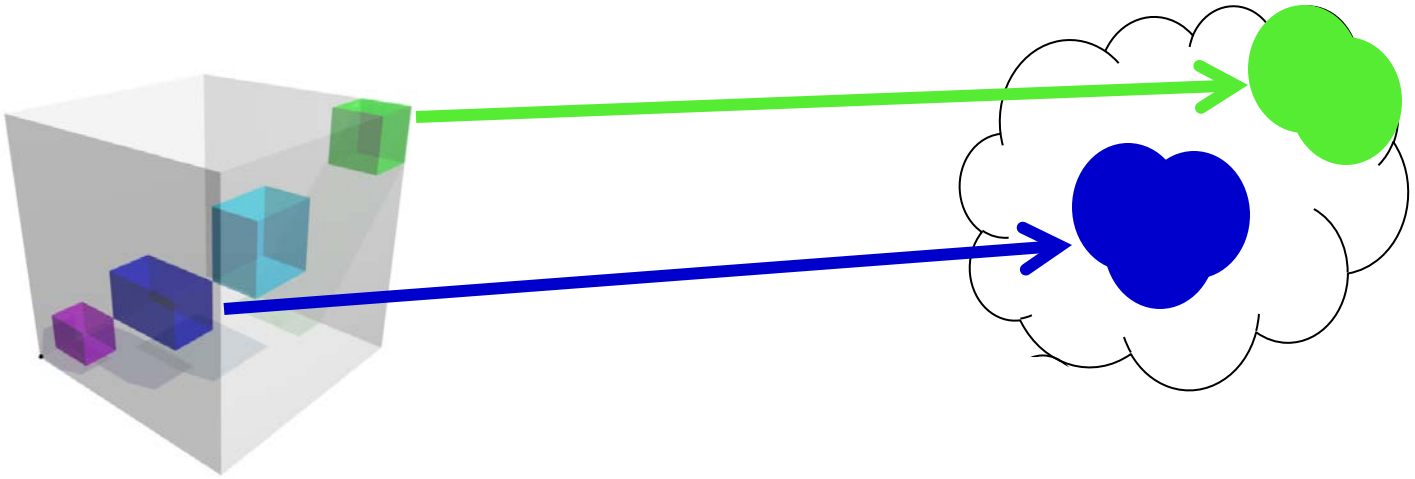


H2: No one approach is always the most appropriate



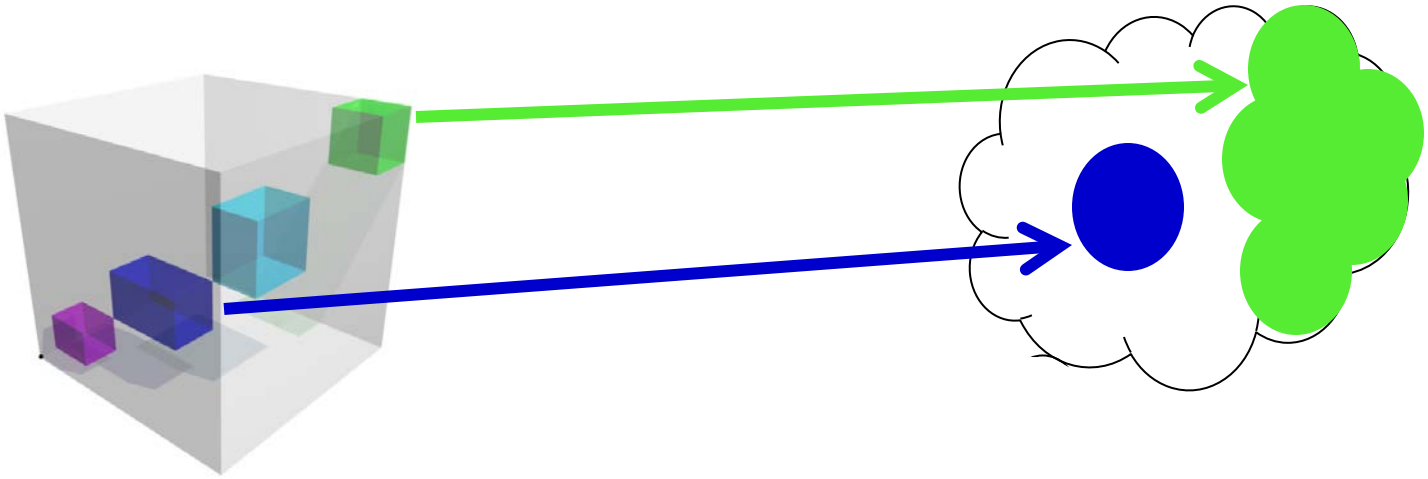
C2 Agility Hypotheses

H3: More network-enabled approaches are more appropriate for Complex Endeavors; while less network-enabled approaches are more appropriate for less complex missions/circumstances



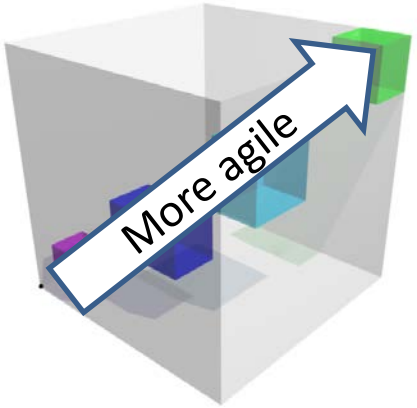
C2 Agility Hypotheses

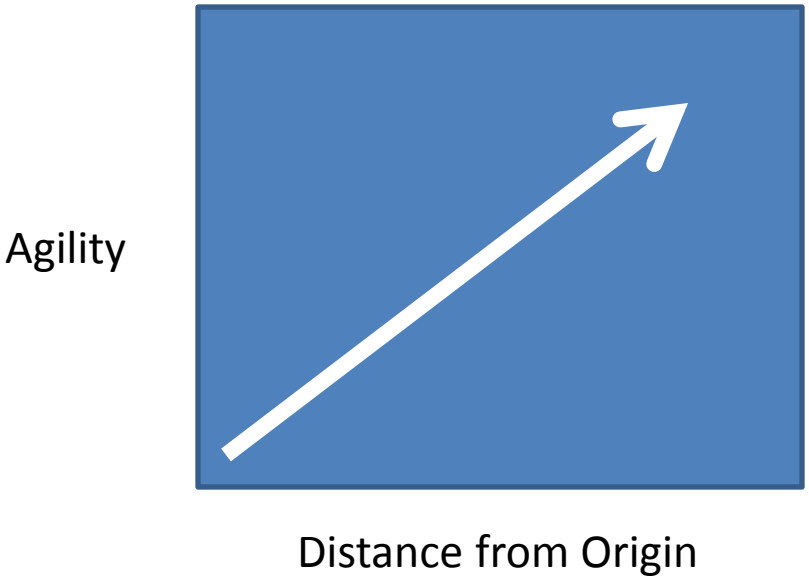
H4: More network-enabled approaches are more agile (have greater C2 Approach Agility)



C2 Agility Hypotheses

H5: The dimensions of the C2 approach Space are positively correlated with agility





C2 Agility Hypotheses

H6: More network-enabled approaches are better able to maintain their intended positions in the C2 Approach Space.

H7: On-diagonal (balanced) approaches are more agile

H8: Increasing C2 Maneuver Agility increases agility

C2 Agility Hypotheses

H9: More mature C2 capability is more agile than the C2 Approach Agility of the most network-enabled approach available

H10: Self monitoring is required for C2 Maneuver Agility

H11: The six enablers of agility are collectively exhaustive and thus all instances of observed agility can be traced to one or more of these enablers

H12: Each of these enablers is positively correlated with agility

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Questions?

Comments?

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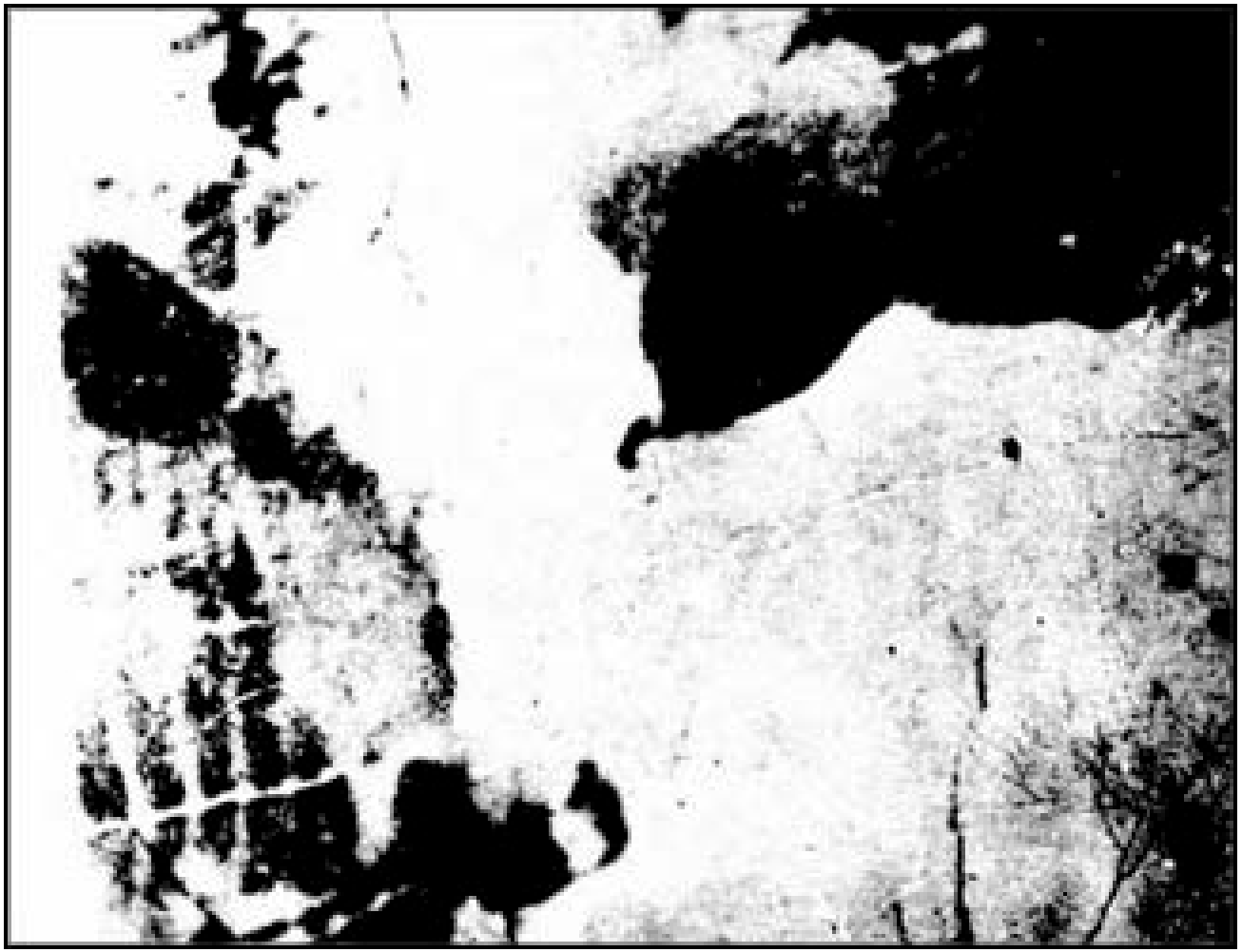
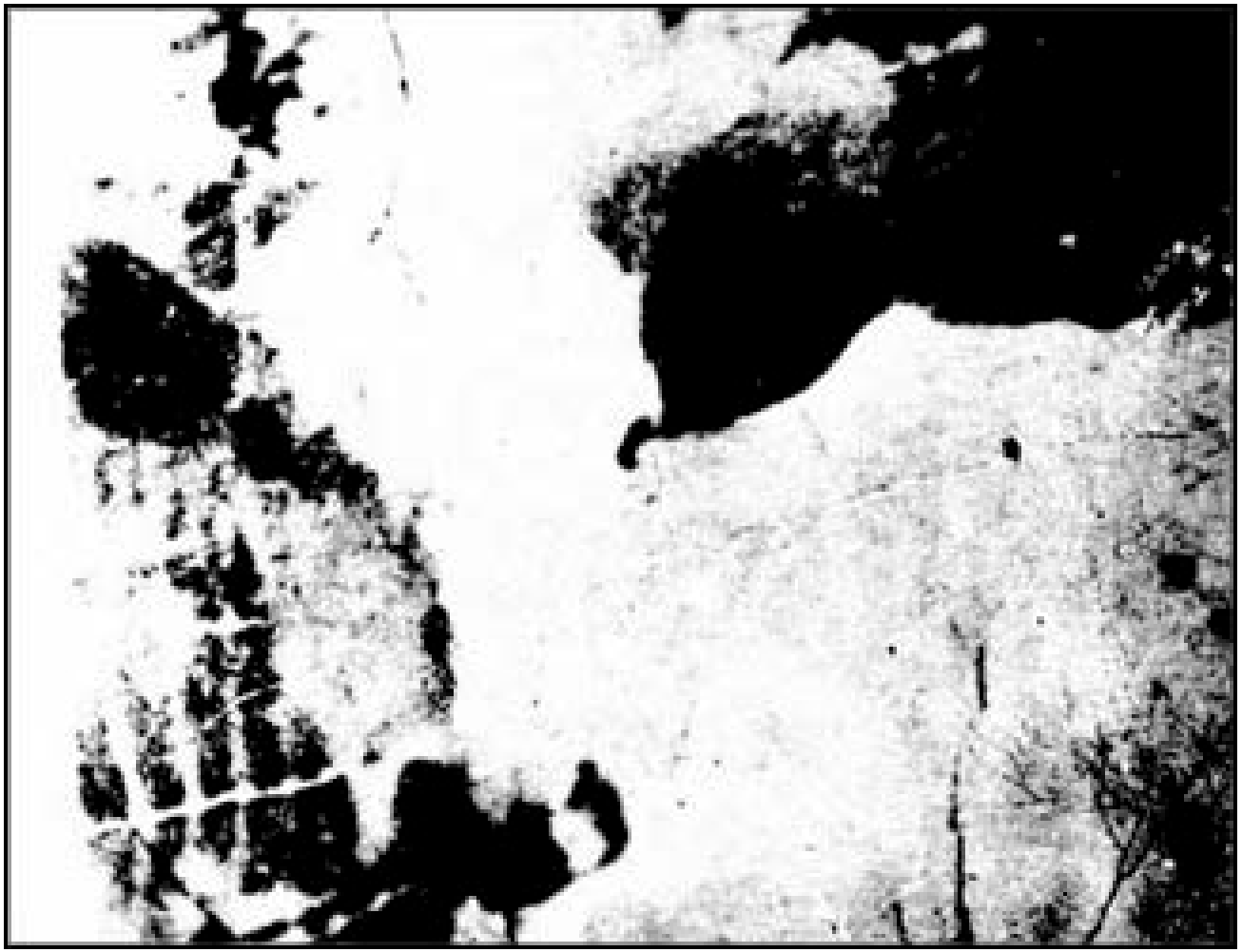
Validation

- Orientation
- Objectives of Validation Effort
- Approach
- Case Studies
- Campaign of Experimentation

A Deductive Approach

- You have seen how the topic of interest, C2 Agility, has been outlined and how we have scoped the topic
- You have seen how we have identified and specified the major concepts and the variables of interest
- The case studies and experiments, using the hypotheses as a framework, enabled SAS-085 to:
  - Find out what is known about the relationships among these concepts and variables
  - Reason logically from what is discovered about the relationships back to the conceptual model and to determine the implications or the 'so-what?' for NATO





It’s a cow !

Source: Dallenbach, K.M. (1951) ‘A puzzle-picture with A new principle of concealment’, *American Journal of Psychology,* Vol.64, pp.431-3.

The Persistence of Established Views

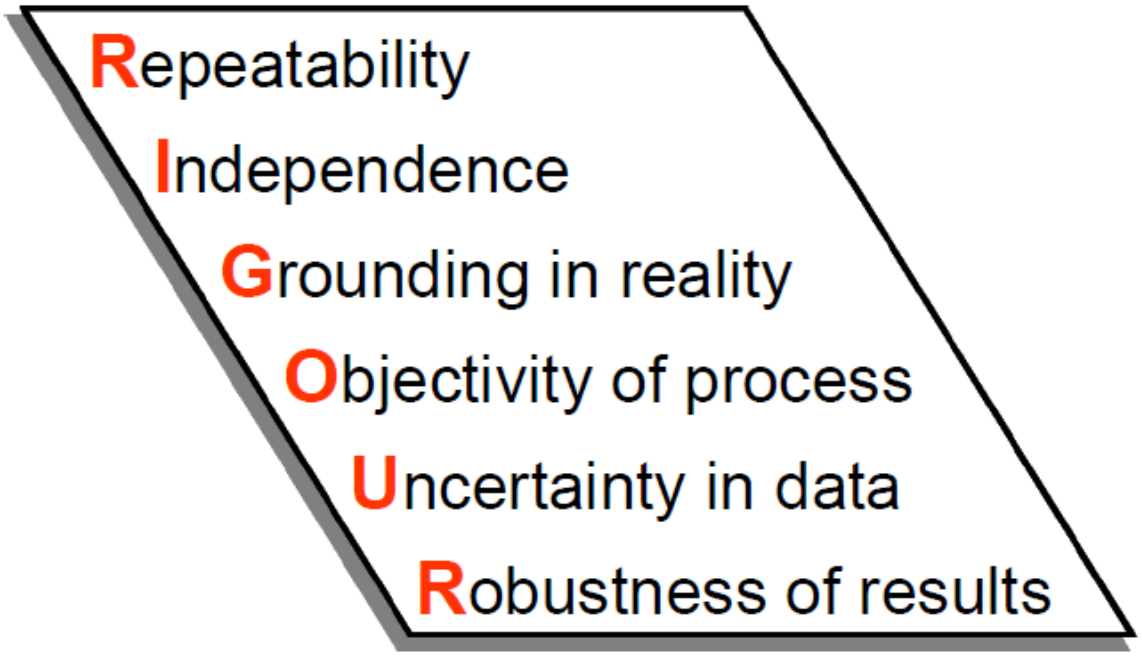
It is difficult to look at the same information from different perspectives.

Taking An Objective View

"All models are wrong but some are useful"

George Box

SAS-085 analysis applied a RIGOURous scientific process



Best Practice for using Assessment Hierarchies in Operational Analysis – Principles and Practical Experiences, Graham Mathieson, 2000

Understanding

is as important as

‘results’

Objectives of Validation Effort

- Clarity
  - Given that C2 Agility is a rich and nuanced concept and NATO is a very diverse alliance, SAS-085 wanted to ensure that its explanations, findings, and conclusions very clear and easy to understand
- Applicability
  - Given that C2 Agility is of more than academic interest, SAS-085 wanted to ensure that the concepts, metrics, and measures could be applied to real world organizations and situations
- Validity
  - The C2 Agility concept embodies a set of testable hypotheses; SAS-085 wanted to empirically test these hypotheses

Validation Approach

- Expert Validity – Does the model appear to be credible to those who are knowledgeable in the field?
  - Could we ourselves understand the concepts well enough to undertake a set of case studies and experiments
  - Peer Review process
- Construct Validity – Does the model include all of the relevant factors and relationships?
  - Could we observe critical aspects of the C2 Agility concept and related behaviors and outcomes in a variety of military and civil-military operations
  - Could we characterize and measure these behaviors and outcomes of interest in case studies and experiments
- Empirical Validity – Does the conceptual model produce the behaviors and results observed in the real world?
  - Are the hypotheses suggested by the model supported by the evidence derived from case studies and experiments

Discussion

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Comments?

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Case Studies

- Background
- Objective
- Methodology
- Evidence Tables
- Concepts that flow from Case Studies
- Hypothesis Findings
- Discussion and Questions

Case Study Background

- Detailed analyses of historical situations where evidence is sought that may confirm (or not) concepts, notions, or hypotheses
- Advantage: any conclusions drawn from the analysis pertain to real situations, thus providing empirical “face” validity.
- Disadvantage: these conclusions pertain only to those situation(s) being analysed, and therefore it becomes difficult to generalise and extrapolate to other situations.

Reasons for Case Study Analyses

Reasons for conducting Case Study analyses are to:

1. Identify key concepts, enablers, constraints, and behaviours related to C2 Approach Agility and C2 Manoeuver Agility in the cases.
2. Help clarify the language of C2 Agility
3. Opportunity to demonstrate and verify that the model, in fact, occurs in the real world
4. Contribute to validation by testing C2 Agility-related hypotheses

Case Study Objective

- Seek evidence for the C2 Agility Conceptual Model, sub-concepts, variables, and variable relationships.

Case Study Methodology

- Develop a Template that reflects CACM
- Collect Evidence based on Template
- Conduct Meta-analysis looking for:
  - Evidence across multiple studies
  - Evidence of new notions for CACM

Case Study Template

The first template was designed to capture relevant source data in one location.

I. Executive Summary

II: Identify the Focus of and the Boundaries for the Case Study

III. Describe the Challenge or Opportunity that gave rise to the need for C2 Approach and C2 Manoeuver Agilities.

IV: What would have been the consequences of a failure to act in a way that demonstrates C2 Approach Agility and C2 Manoeuver Agility?

V: Was C2 Approach Agility and C2 Manoeuver Agility Manifested? If so, How?

VI: Which Enablers and Inhibitors of C2 Approach Agility were observable?

VII: What C2 Approaches were relevant (i.e., did different situation complexity levels require a corresponding different C2 Approach)? How can C2 Manoeuver Agility be inferred from what was reported or observed?

VIII: What interesting and important vignettes are included or can be derived from the case study to help create illustrative stories?

IX: Case Study Assumptions and Limitations:

Case Study Interim Products

- Phister, P. W. (2012). *Humans and Their Impact on Cyber Agility*. Paper presented at the 17th International Command and Control Research and Technology Symposium: Operationalizing C2 Agility. Washington D.C., USA. (former SAS-085 member)
- Henshaw, M., Tetlay, A., & Siemieniuch, C. (2013). *SAS-085 Case Study – Estonia: Estonia Cyber Attack in Spring 2007*. Engineering System of Systems Group, School of Electronic, Electrical and Systems Engineering Loughborough University (UK), Loughborough, UK.
- Meijer, M. (2012). *Consequences of the NATO Comprehensive Approach for Command and Control*. Paper presented at the 17th International Command and Control Research and Technology Symposium: Operationalizing C2 Agility. Washington D.C., USA.
- Mitchell, W. (draft). *Case Study Report Generated as an Official Danish Defence Contribution to NATO SAS-085*. Royal Danish Defence College.
- Basini, C. (draft). *Italian Civil Protection's Operation after the Garda Earthquake, Province of Brescia, 2004 : A Case Study for NATO SAS085 on C2 Agility and Requisite Maturity*. Swedish National Defence College.
- Banbury, S., Kelsey, S. R., & Kersten, C. (2011). Evaluating C2 Approach Agility in Major Events: Final Report (CONTRACT #: W7714-083663/001/SV No. DRDC CR 2011-004). Scientific Authority Dr. Philip S. E. Farrell. Centre for Operational Research and Analysis (CORA), Ottawa, Ontario, Canada: Defence R&D Canada.
- Jobidon, M.-E., Fraser, B., Smith, D., & Farrell, P. S. E. (2011). *Analysis of GM approach agility during the Vancouver 2010 Olympic Games* (Technical Memorandum). Toronto: DRDC Toronto TM 2011-124.
- Farrell, P. S. E., Jobidon, M.-E., & Banbury, S. (2012). *Organizational Agility Olympic Event Case Studies.* Paper presented at the 17th International Command and Control Research and Technology Symposium: Operationalizing C2 Agility. Washington D.C., USA.
- Bélanger, M. (2013). *The difficulty to document agility evidences from a C2 perspective.* Paper presented at the 18th International Command and Control Research and Technology Symposium: C2 in Underdeveloped, Degraded and Denied Operational Environments. Alexandria, VA., USA.
- Farrell, P. S. E., Baisini, C., Bélanger, M., Henshaw, M., William, M., Norlander, A. (2013). *SAS-085 C2 Agility Model Validation Using Case Studies. .* Paper presented at the 18th International Command and Control Research and Technology Symposium: C2 in Underdeveloped, Degraded and Denied Operational Environments. Alexandria, VA., USA.

Case Study Template

The second template was designed to summarize evidence for each notion, sub-concept, and variable for each case study.

Concept/Component	
C2 Manoeuver Agility	*See C2 Manoeuver Agility on page 67*
Endeavour Space Complexity	*See Complexity on page 16* *The Endeavour Space Complexity values: low, medium, and high*
Appropriate (Required) C2 Approach	*See C2 Manoeuver Agility on page 67; Figure 4.4* *Labels: De-conflicted, Coordinated, Collaborative, Edge*
C2 Approach Space	*See C2 Approach Space on page 24*
Allocation of Decision Rights	*See Allocation of Decision Rights in Glossary* *ADR varies from None to Broad.*
Distribution of Information	*See Distribution of Information in Glossary* *DoI varies from None to Broad.*
Patterns of Interaction	*See Patterns of Interaction in Glossary* *PoI varies from Constraint to Unconstraint.*
Actual C2 Approach	*See Approaches to Command and Control on page 64*
Self-Monitoring	*See C2 Agility and Self-Monitoring on page 73*
C2 Approach Agility	*See C2 Approach Agility on page 66* *Enabler (or opposite) values: low, medium, and high.*
(Lack of) Flexibility	*See Flexibility in Glossary*
(Lack of) Adaptiveness	*See Adaptiveness in Glossary*
(Lack of) Responsiveness	*See Responsiveness in Glossary*
(Lack of) Versatility	*See Versatility in Glossary*
(Lack of) Innovativeness	*See Innovativeness in Glossary*
(Lack of) Resilience	*See Resilience in Glossary*

Case Study Template (fictitious)

Concept/Component	Phase 1	Phase 2	Phase 3
C2 Manoeuver Agility			
Endeavour Space Complexity	High	Medium	Low
Appropriate (Required) C2 Approach	Collaborative	Coordinated	De-conflicted
C2 Approach Space			
Allocation of Decision Rights	Somewhat broad	Narrow	Narrow
Distribution of Information	Broad	Broad	Not as Broad
Patterns of Interaction	Constrained	Constrained	Constrained
Actual C2 Approach	Between Collaborative and De-conflicted	Between Coordinated and De-conflicted	Closer to De-conflicted
Self-Monitoring	None	√	√
C2 Approach Agility			
Flexibility	√	?	?
Adaptiveness	√	√	?
(Lack of Responsiveness)		High	?
Versatility	√	√	?
(Lack of Innovativeness)	√	√	Low
Resilience	Medium	?	?

Case Studies

Complex Battlespace

Helmand Province, Dr. William Mitchell, Royal Danish Defence College, **Denmark**

Comprehensive Approach in NATO Operations, Cdr Marten MEIJER PhD, C2 CoE, **NLD**

Peace-keeping and Personal Agility

Rwanda Genocide 1994, Micheline Bélanger, Defence R&D Canada – Valcartier, **Canada**

Cyber Warfare

Estonia Cyber Attack 2007, Prof. Michael Henshaw, Loughborough University, **UK**

Georgia, Douglas J. Ball, M.D., *UNC Chapel Hill Gillings School of Global Public Health,* ***USA***

Natural Disasters

Garda Earthquake 2004, Claudia Baisini, Swedish National Defence College, LTC Arne Norlander, **Sweden**

Haiti Earthquake 2010, Dr. Richard Hayes, Evidence Based Research, **USA**

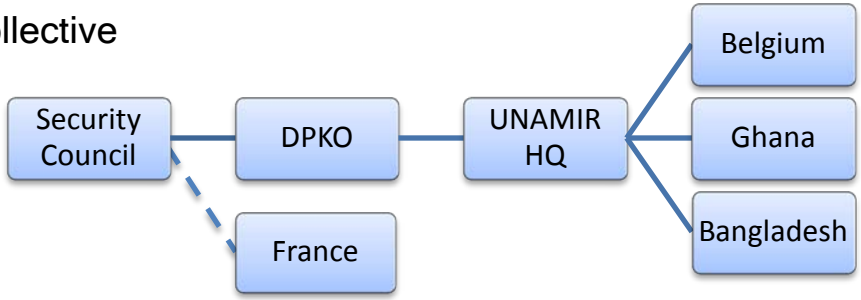
Major Events

Munich Olympics 1972, Dr. Philip S. E. Farrell, Defence R&D Canada – Toronto, **Canada**

Vancouver Olympics 2010, Dr. Philip S. E. Farrell, Defence R&D Canada – Toronto, **Canada**

Case Study – UNAMIR (United Nations Mission for Rwanda)

- UN Mission
  - To assist in implementing peace accords between the Rwandan government (controlled by Hutus) and the Rwandese Patriotic Front (RPF).
- Event Analyzed
  - Massive Rwanda Genocide executed by Hutu extremists against Tutsi in 1994 (Up to 800,000 people were murdered)
- Collective



	I	II	III	IV
Phase	UN Security Assistance Mission	Violence Escalation	Monitoring Mission	Security and Protection of Refugees and Civilians
From	5 October 1993	6 April 1994	21 April 1994	17 May 1994
To	6 April 1994	21 April 1994	17 May 1994	18 July 1994




Case Studies Evidence Table

Rwanda: UNAMIR HQ – UN DPKO

Component/Concept	Phase 1	Phase 2	Phase 3	Phase 4
C2 Manoeuver Agility		√		
Endeavour Space Complexity	medium	high	high	High
Appropriate (Required) C2 Approach				
C2 Approach Space				
Allocation of Decision Rights	limited	Limited / broad	limited	Limited
Distribution of Information	broad	broad	broad	Broad
Patterns of Interaction	As required	As required – significant broad	As required	As required
Actual C2 Approach	Collaborative	Collaborative / Edge	Collaborative	Collaborative
Self-Monitoring	Was done continuously	Recognized the need to change C2 Approach	Was done continuously	Was done continuously
C2 Approach Agility				
Flexibility)		Evidence Found		
Adaptiveness		Evidence Found		
Responsiveness		Evidence Found		
Versatility				
Innovativeness				
Resilience				

Case Studies Evidence Table

Rwanda: UNAMIR HQ – Media

Component/Concept	Phase 1	Phase 2	Phase 3	Phase 4
C2 Manoeuver Agility		√		
Endeavour Space Complexity	Medium	high	high	high
Appropriate (Required) C2 Approach				
C2 Approach Space				
Allocation of Decision Rights	None	Emergent	Emergent	Emergent
Distribution of Information	Limited	All Relevant Information	All Relevant Information	All Relevant Information
Patterns of Interaction	Limited, Sharply Focused	As Required	As Required	As Required
Actual C2 Approach	Conflicted	Conflicted / Coordinated	Coordinated	Coordinated
Self-Monitoring	Continuous	Continuous/Recognized the need to change approaches	Continuous	Continuous
C2 Approach Agility				
Flexibility		Evidence Found	Evidence Found	Evidence Found
Adaptiveness				
Responsiveness				
Versatility				
Innovativeness		Evidence Found	Evidence Found	Evidence Found
Resilience				

Case Studies Evidence Table

Estonia Cyber Attack 2007: Defender Perspective

Concept/Enabler	Phase 1	Phase 2 Wave 1	Phase 2 Wave 2
Defender Perspective (Estonia)			
C2 Manoeuver Agility			
Endeavour Space Complexity	High	High	Medium - High
Appropriate (Required) C2 Approach CYBER only	Collaborative	Collaborative	Collaborative
Appropriate (Required) C2 Approach WIDER conflict	Coordinated	Coordinated	Coordinated
C2 Approach Space			
Allocation of Decision Rights	Wide	Wide	Wide
Distribution of Information	Broad	Broad	Broad
Patterns of Interaction	Unconstrained	Unconstrained	Unconstrained
Actual C2 Approach CYBER only	Coordinated	Collaborative	Collaborative
Actual C2 Approach WIDER conflict	De-conflicted	De-conflicted	De-conflicted
Self-Monitoring	None	Began to understand effect of defensive actions	Began to establish future capabilities based on learning
C2 Approach Agility			
Flexibility	High	High	High
Adaptability	Low	Medium	Low
Responsiveness	High	High	High
Versatility	High	High	High
Innovativeness	Low	Medium	Low
Resilience	High	High	High

Case Studies Evidence Table

Estonia Cyber Attack 2007: Attacker Perspective

Concept/Enabler	Phase 1	Phase 2 Wave 1	Phase 2 Wave 2
Attacker Perspective			
C2 Manoeuver Agility			
Endeavour Space Complexity	High	High	Medium - High
Appropriate (Required) C2 Approach CYBER only	Coordinated + Edge	Coordinated + Edge	Coordinated + Edge
Appropriate (Required) C2 Approach WIDER conflict	Coordinated	Coordinated	Coordinated
C2 Approach Space			
Allocation of Decision Rights	Wide	Wide	Wide
Distribution of Information	Broad	Broad	Broad
Patterns of Interaction	Unconstrained	Unconstrained	Unconstrained
Actual C2 Approach CYBER only	Edge	Coordinated + Edge	Coordinated + Edge
Actual C2 Approach WIDER conflict	Coordinated	Coordinated	Coordinated
Self-Monitoring	None	None	None
C2 Approach Agility			
Flexibility	Medium	Low	Low
Adaptability	Medium	Medium	Low
Responsiveness	Low	Low	Low
Versatility	Low	Low	Low
Innovativeness	Medium	Medium	Low
Resilience	Low	Low	Low

Case Studies Evidence Table

Georgia

Concept/ Component	Russian Cyber Militia	Russian Military	Russian Power Agencies	Russian Collective	Georgian Cyber Experts	Georgian Military	Georgian Civil	Georgian Collective
C2 Manoeuver Agility								
Endeavour Space Complexity				High				High
Appropriate (Required) C2 Approach								
C2 Approach Space								
Allocation of Decision Rights	broad			narrow				narrow
Distribution of Information	broad			Between narrow and broad				Between narrow and broad
Patterns of Interaction	Un-constrained	constrained		Unconstrained				Between constrained and unconstrained
Actual C2 Approach	Edge	Between Co-ordinated and Conflicted	Mainly Collaborative to De-conflicted	Between Co-ordinated and Conflicted	Edge	Between Collaborative and De-conflicted	Mainly Co-ordinated to De-conflicted	Between Collaborative and De-conflicted
Self-Monitoring				√				
C2 Approach Agility								
Flexibility				High				High
Adaptiveness								High
Responsiveness								High
Versatility								
Innovativeness				High				
Resilience								

Case Studies Evidence Table

Garda Earthquake 2004

Concept/Component	Phase 1 Emergency	Phases 2 & 3 Stabilization & Reconstruction
C2 Manoeuver Agility		
Endeavour Space Complexity	High	Medium to low
Appropriate (Required) C2 Approach		
C2 Approach Space		
Allocation of Decision Rights	Broad moving to less Broad	More centralized
Distribution of Information	Broad moving to less Broad	More structured
Patterns of Interaction	Unconstrained moving to more formal interactions	More regular and less intense
Actual C2 Approach	Edge	Collaborative to more Coordinated
Self-Monitoring		
C2 Approach Agility		
Flexibility		
Adaptiveness		√
Responsiveness	√	
Versatility	√	
Innovativeness		√
Resilience	√	√

Case Studies Evidence Table

Haiti Earthquake 2010

Concept/Component	Phase 1 Search & Rescue Jan 13 – 22, 2010	Phase 2 Disaster Relief Jan 17 – Feb 1	Phases 3 Stabilization & Transition Feb 2 – March
C2 Manoeuver Agility			
Endeavour Space Complexity	High	High to Medium	Medium to low
Appropriate (Required) C2 Approach			
C2 Approach Space			
Allocation of Decision Rights	Narrow	Narrow	Less narrow
Distribution of Information	No distribution	Narrow	Less narrow
Patterns of Interaction	Less Constrained	Less Constrained	Somewhat Unconstrained
Actual C2 Approach	Conflicted to De-conflicted	De-conflicted	Coordinated
Self-Monitoring			
C2 Approach Agility			
Flexibility	High		
Adaptiveness	High		
Responsiveness	High		
Versatility	Medium		
Innovativeness	High		

Case Study Evidence Table

Munich Olympics 1972

Case Study Evidence Table

Munich Olympics 1972

Concept/Component	Phase 1 Pre-terrorist attack	Phase 2 Hostages in apartment	Phase 3 Apartment to airfield	Phase 4 At the airfield	Phase 5 Post-terrorist attack
C2 Manoeuver Agility					
Endeavour Space Complexity	Low	Medium	High	Very High	
Appropriate (Required) C2 Approach	Coordinated	Coordinated	Coordinated	Collaborative	Coordinated
C2 Approach Space					
Allocation of Decision Rights	None	Somewhat Narrow	None	Complete Breakdown	
Distribution of Information	Low (radios only)	Low	None	Incorrect Info	
Patterns of Interaction	None	Somewhat constrained	None (out of control)	Complete Breakdown	
Actual C2 Approach	Conflicted (Independent)	De-conflicted	Conflicted	Worse than Conflicted (Anarchic)	
Self-Monitoring					
C2 Approach Agility					
Flexibility		√			
Adaptiveness	No Evidence	No Evidence	No Evidence	No Evidence	
(Lack of Responsiveness)	High	High	High	High	
(Lack of Versatility)	High	High	High	High	
Innovativeness					
Resilience	No Evidence	√	No Evidence	No Evidence	

Case Study Evidence Table

Vancouver Olympics 2013

- During the 3-year **pre-event** phase, agility was manifested in coping with complexity in 'self' as primarily being a clash of organizational cultures.
  - Military Commander makes the decision
    - ADR top down
    - PI hierarchy
    - DI fairly broad (need to know)
  - Cop on the beat makes the decision
    - ADR bottom up
    - PI inverted hierarchy
    - DI very narrow (litigation)

- **During the event,** the games went to plan without any major incident.

Case Study Evidence Table

Vancouver Olympics 2010

Concept/Component	Phase 1 Before Event	Phase 2 During Event	Phase 3 After Event
C2 Manoeuver Agility			
Endeavour Space Complexity	Low to med high	low	low
Appropriate (Required) C2 Approach	De-conflict to Collaborative	De-conflicted	De-conflicted
C2 Approach Space			
Allocation of Decision Rights	Narrow then somewhat broad	Somewhat broad	None
Distribution of Information	Broad capability available	Fairly broad	No need to be broad
Patterns of Interaction	Started constrained, ended somewhat constrained	Somewhat constrained	constrained
Actual C2 Approach	Started de-conflicted, ended around coordinated	Coordinated	Between De-conflicted and coordinated
Self-Monitoring	Scripted	No opportunity	NA
C2 Approach Agility			
Flexibility	No opportunity	No opportunity	NA
Adaptiveness	No opportunity	No opportunity	NA
(Lack of Responsiveness)	√	No opportunity	NA
(Lack of Versatility)	√	√	NA
Innovativeness	No opportunity	No opportunity	NA
Resilience	No opportunity	No opportunity	NA

Case Study Evidence Table

Helmand Province 2010-2011

Concept/Component	Aug 2010 (Phase 1)	Sept 2010 (Phase 2)	Oct 2010 (Phase 3)	Nov 2010 (Phase 4)	Dec 2010 (Phase 5)	Jan 2011 (Phase 6)
C2 Manoeuver Agility						
Endeavour Space Complexity	(Very) High	(Very) High	(Very) High	(Very) High	(Very) High	(Very) High
Appropriate (Required) C2 Approach	Edge	Edge	Edge	Edge	Edge	Edge
C2 Approach Space						
Allocation of Decision Rights	Narrow (isolated)	Narrow (isolated)	Less Narrow (expanding network awareness)	Broad (expanding network awareness)	Broad (expanding network awareness)	Broad (expanding network awareness)
Distribution of Information	Vertical Narrow Push	Vertical Narrow Push	Vertical/Lateral "push-pull"	Lateral "push-pull"	Lateral Push-pull	Lateral push-pull
Patterns of Interaction	Tightly constrained	Tightly constrained	Constrained	Unconstrained	Un-constrained	Un-constrained
Actual C2 Approach	Conflicted	Conflicted	De-conflicted	Edge	Edge	Edge
Self-Monitoring	None	None	None	Recognized the need to change approaches	Recognized the need to change approaches	Recognized the need to change approaches
C2 Approach Agility						
Flexibility	Low	Low	Med	Med High	High	High
Adaptiveness	Low	Low	Med	Med high	High	High
Responsiveness	Low	Low	Med	Med High	High	High
Versatility	Low	Low	Med	Med High	High	High
Innovativeness	Low	Low	Med	Med High	High	High
Resilience	Med High	Med High	Med High	Med High	High	High

Summary of Case Study Evidence

Concept / Component	Rwanda DPKO	Rwanda Media	Estonia Cyber Attack	Georgia Cyber Attack	Garda Earthquake	Haiti Earthquake	Munich Olympics	Vancouver Olympics	Helmand Province
C2 Manoeuver Agility					✓				✓
Endeavour Space Complexity	✓	✓	✓	✓		✓	✓	✓	✓
Appropriate (Required) C2 Approach			✓				✓	✓	✓
C2 Approach Space									
Allocation of Decision Rights	✓	✓	✓	✓	✓	✓	✓	✓	✓
Distribution of Information	✓	✓	✓	✓	✓	✓	✓	✓	✓
Patterns of Interaction	✓	✓	✓	✓	✓	✓	✓	✓	✓
Actual C2 Approach	✓	✓	✓	✓	✓	✓	✓	✓	✓
Self-Monitoring	✓	✓	✓					✓	✓
C2 Approach Agility	✓	✓							
Flexibility	✓	✓	✓	✓		✓	✓		✓
Adaptiveness	✓		✓	✓	✓	✓			✓
Responsiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓
Versatility			✓		✓	✓	✓	✓	✓
Innovativeness		✓	✓	✓	✓	✓			✓
Resilience			✓		✓		✓		✓

Case Study Observations

- Anticipation
- Leadership
- Collective size changes over time
- C2 Approach Heterogeneity within Collective
- Comfortable C2 Approach
- Risk Assessment
- Competency as an enabler
- Trust and Interpersonal Relationships
- Conflicted vs. Independent C2
- Politically driven C2 Approach
- Off-diagonal C2 Approaches
- C2 Agility as an emergent phenomenon (not intentionally designed)

Hypothesis Related Findings from Case Studies

Hypothesis	Evidence Found
H1: Distant C2 Approaches	yes
H2: No 'one-size'	not clear
H3: Network-enabled - Challenging	yes
H4: Net-enabled - Agility	insufficient
H5: Approach Space – Agility	n/a
H6: Network-enabled - Position	n/a
H7: on v off diagonal C2 Approaches	n/a
H8: C2 Manoeuver - Agility	yes, limited
H9: C2 Maturity - Agility	insufficient
H10: Self-monitoring - Agility	yes
H11: Components	yes, limited
H12: Components - Agility	yes, selected cases

Discussion

Questions?

Comments?

Agenda

- Objectives
- Basics of Agility
- Evolution of Command and Control
- C2 Agility
- C2 Agility Hypotheses
- Validation Approach
- Case Studies
- Campaign of Experimentation
- Summary of Findings, Conclusions, and Way Ahead

Campaign of Experimentation

- Purpose
- Methodology
- Experimental Platforms
- C2 Approaches Tested
- Results
- Summary

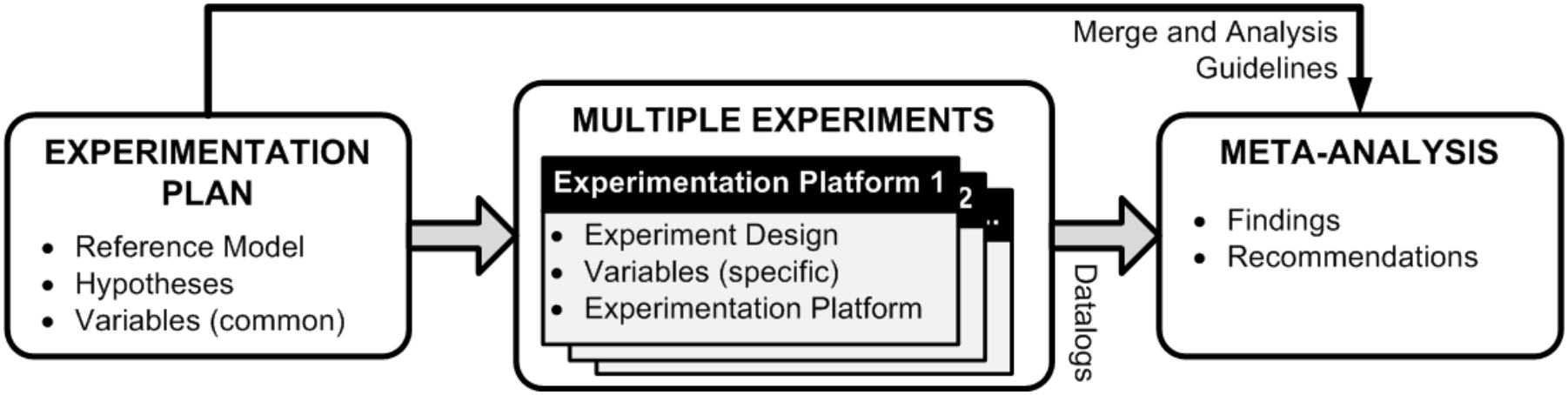
CoE Purpose

Contribute to the validation of the C2ACM by conducting multiple simulation-based experiments within the context of an overarching Campaign of Experimentation (CoE) that

- creates a rich set of empirical data
- tests a set of agility-related hypotheses

CoE Methodology

- The method followed is based on the prospective meta-analysis methodology in order to produce a more complete, robust and generalizable set of findings than summarizing multiple independent experiments



CoE Experimental Platforms

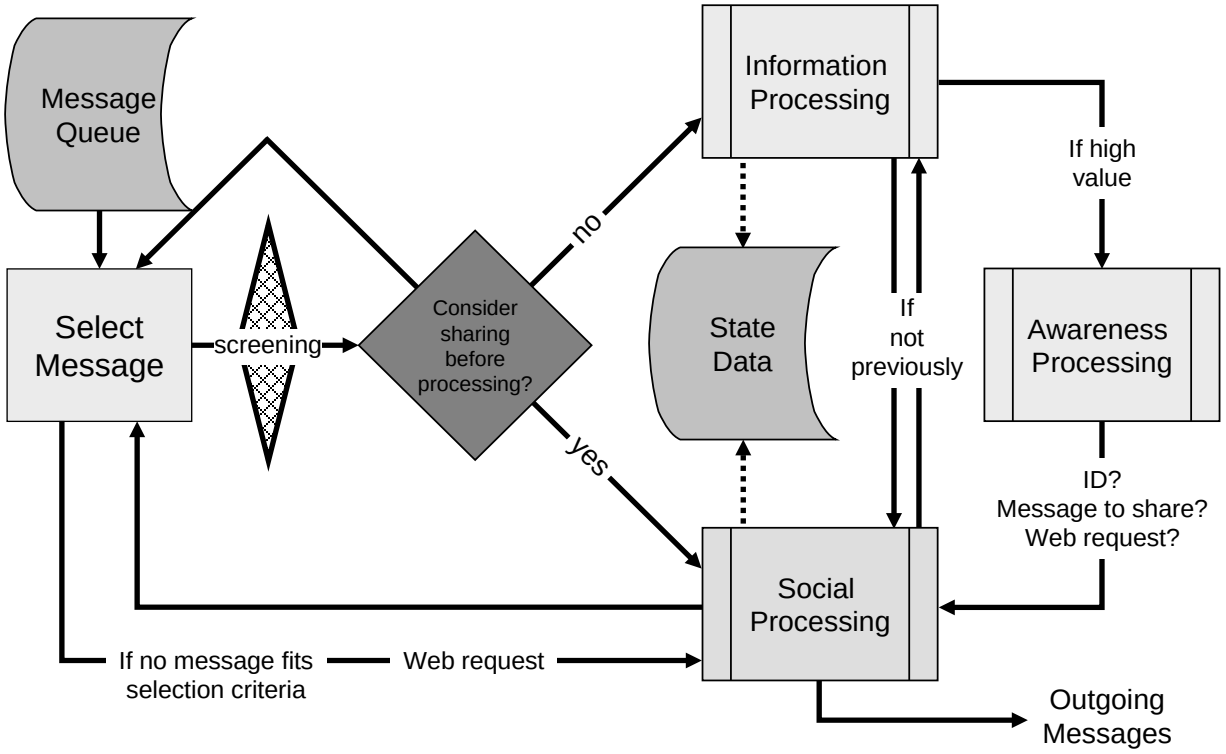
All experimental platforms are constructive agent-based simulations, each of which instantiates at least two C2 Approaches and simulates a variety of circumstances

- ELICIT: Scenario that finds the Who, What, Where and When of a terrorist attack. There are three variants:
  - ELICIT-IDA (U.S.A.)
  - abELICIT (Portugal)
  - ELICIT-TRUST (U.S.A.): agents are influenced by trust
- IMAGE (Canada): Multi-agency stabilization operation
- WISE (U.K.): Air and maritime support to land operation
- PANOPEA (Italy): Maritime counter-piracy operation

ELICIT Implementation

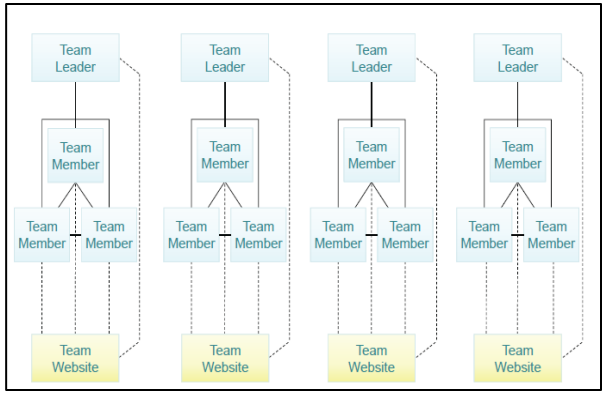
ELICIT-IDA, abELICIT

- Sensemaking agents developed (abELICIT) with parameters to vary the capability and behavior of agents during experiments

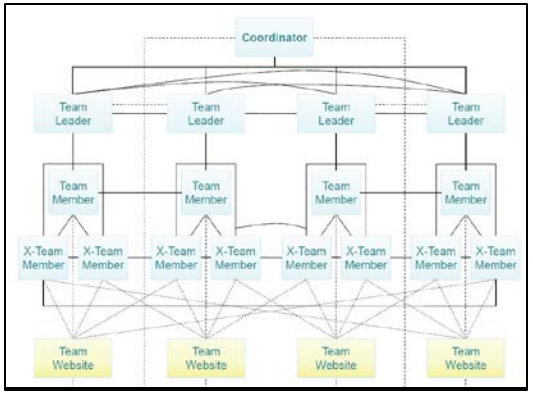


ELICIT

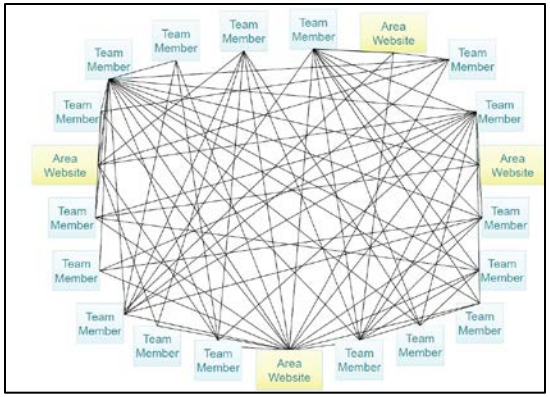
- ELICIT is a DoD CCRP developed experiment platform testing the ability of entities to solve a hidden profile problem for a fictitious terrorist threat
- Originally designed to test various hypotheses between the performance of traditional hierarchical and edge organizations



Conflicted



Collaborative



Edge

ELICIT-TRUST

- C2 environments will exist in situations where entities do not trust or there is uncertainty with regard to the behavior of others in the Collective
- ELICIT-TRUST implements sharing behavior between nodes based on trust estimate of other agents
- Trust is a function of competence and willingness.
- Trust evolves according to Bayesian models and agents adapt their behaviors based on estimated trust of neighboring entities
- Communication network effects degrade the flow of information

ELICIT Experiment Endeavor Spaces

	ELICIT-IDA	ELICIT-TRUST	abELICIT
Self	Network damage	Message/Drop rates	Infostructure degradation
		Trust	Agent performance
		Selfishness	Organisation disruption
Environment	Challenge		Key information available
	Noise in information		
	Cognitive complexity		

IMAGE

- IMAGE is a complexity comprehension tool augmented with software agents that deliberate and act according to rules that comply as much as possible with N2C2M2 theory
- The scenario involves multiple organizations that try to secure and stabilize the failing state by using a comprehensive approach

Canadian

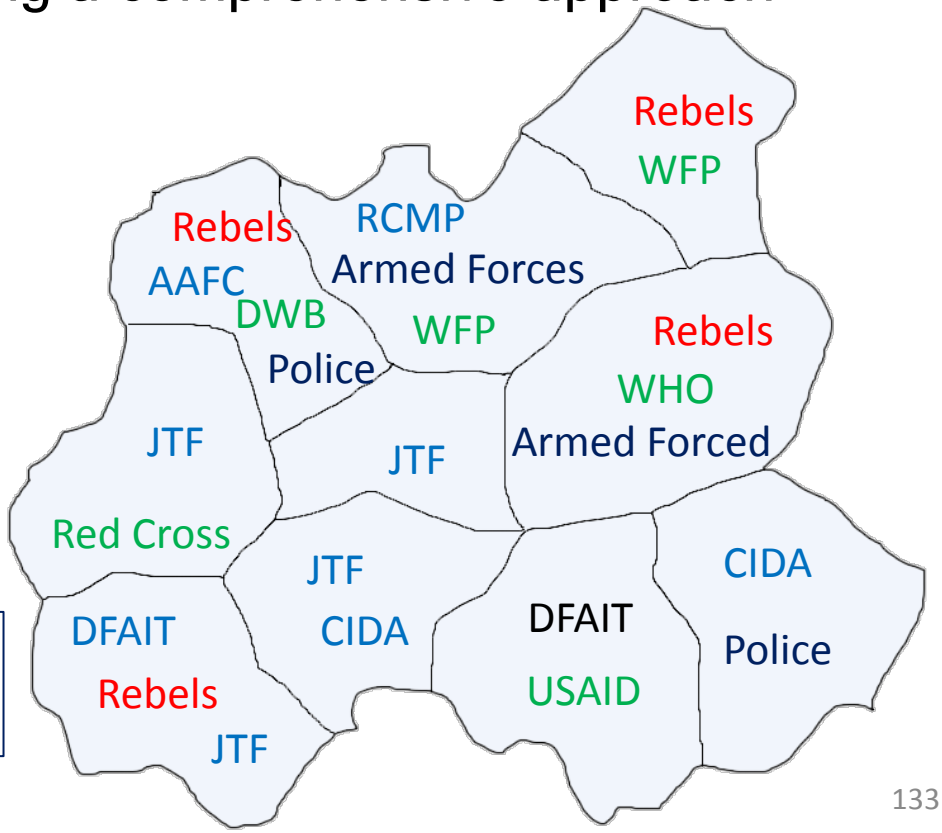
JTF: Joint Task Force
AAFC: Agriculture Canada
CIDA: Canadian International Dev. Agency
DFAIT: Foreign Affair and Int. Trade Canada
RCMP: Royal Canadian Military Police

International

DWB: Doctor Without Border
WHO: World Health Organization
WFP: World Food Program
Red Cross
USAID: US Agency Inter. Devel.

Local

Armed forces
Police



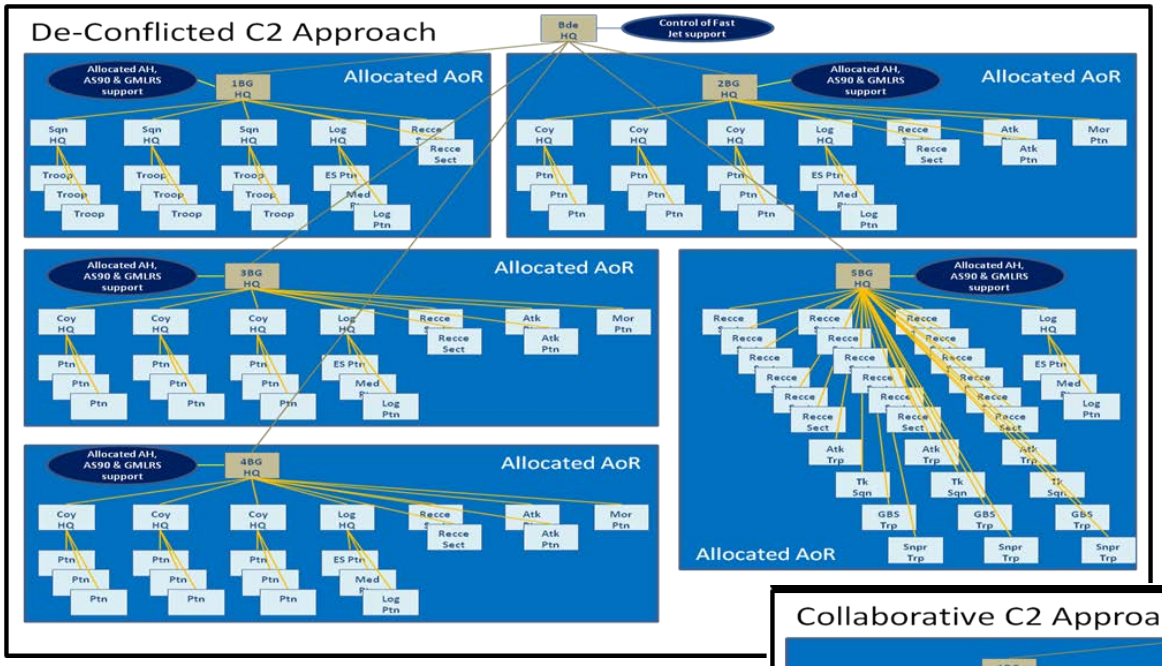
IMAGE

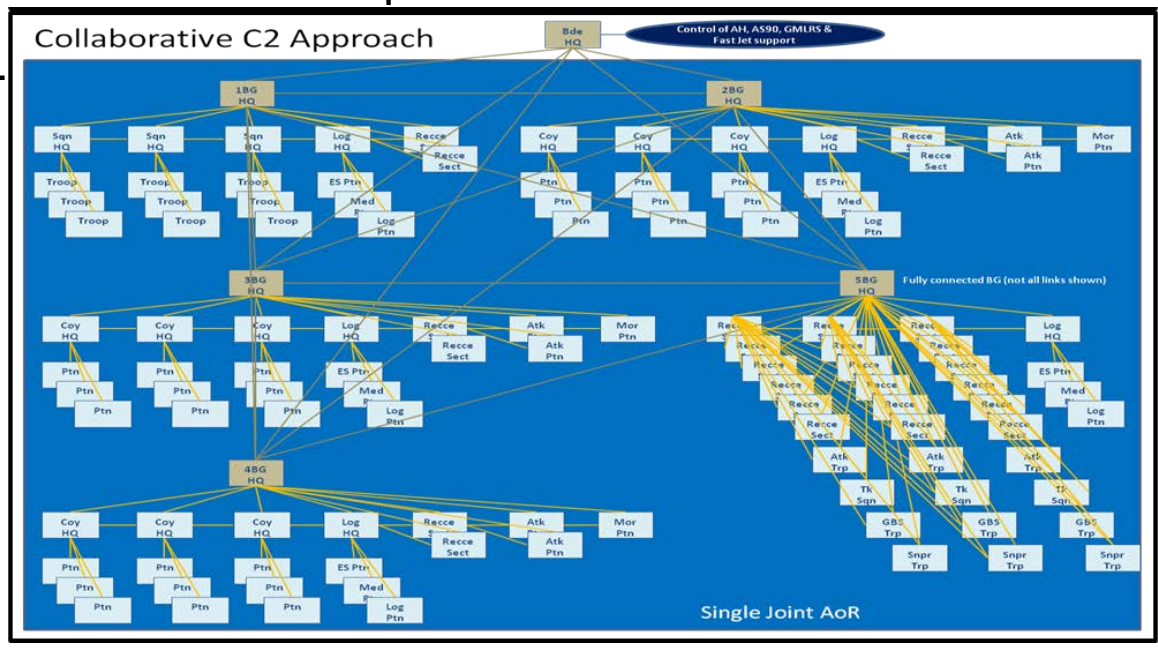
C2 Approach	Allocation of Decision Rights to the Collective	Patterns of Interaction among Entities	Distribution of Information among entities
Conflicted	Each organization decides of its unit locations and activities	Between units of the same organization	Between units of the same organization
De-conflicted	Each organization decides on its unit locations and non-conflicting activities	With organizations having collocated units for preventing conflicting activities	Variables shared instantly between organizations having collocated units
Coordinated	Like in De-Conflicted but interacting activities are considered first with collocated units	With organizations having collocated units for considering interacting activities	Like in De-Conficted + variables shared with 5 non-collocated units (delay: 5 iter)
Collaborative	All activities and unit locations are decided collectively	With all organizations for deciding unit locations and activities.	Same as coordinated but with any number of units (delay 3 iter.)

WISE

- The Wargame Infrastructure and Simulation Environment (WISE) is a Land focused C2 model with representation of air and maritime support to Land operations at the system level
- The scenario simulates a failing state that is experiencing internal conflict. The central government has invited a NATO coalition to stabilize the country
- The UK operation represents a brigade size operation with the specific intent of clearing insurgents from a major urban area
- WISE represented degraded conditions within the brigade operational area by varying the quality of battlefield communication

WISE

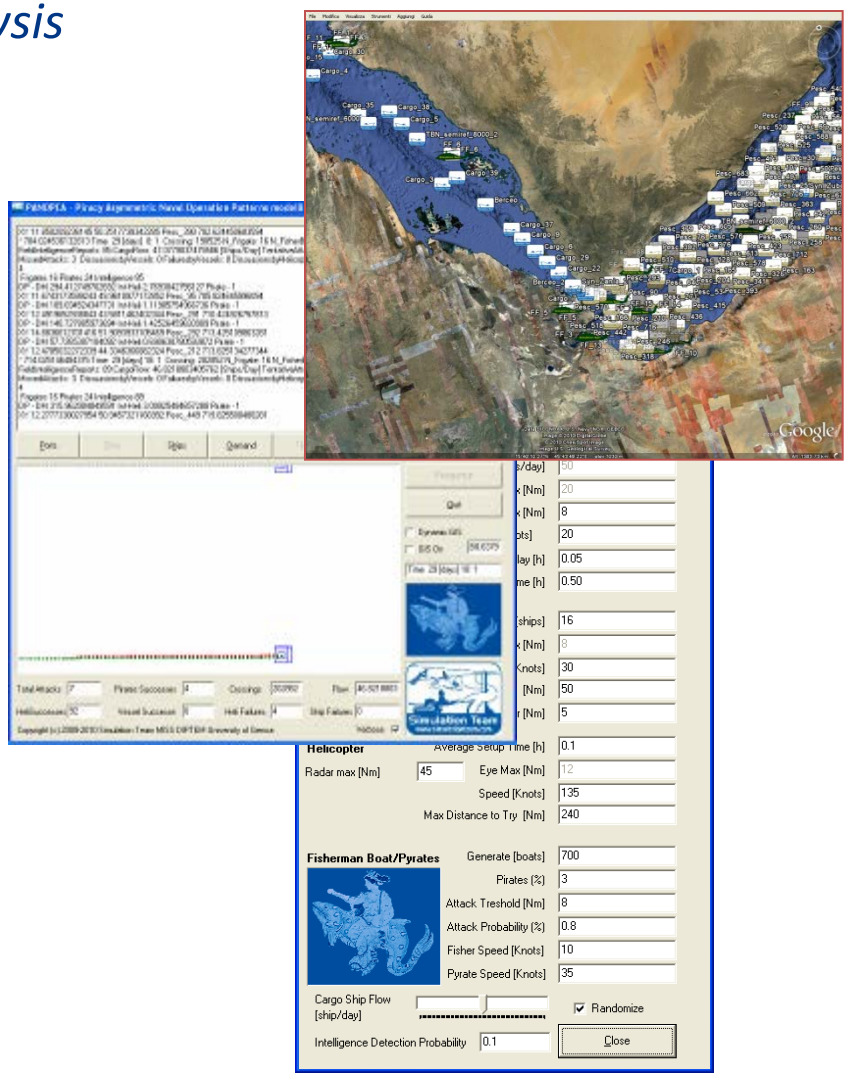

De-Conflicted C2 Approach
Bde HQ
Control of Fast Jet support
1BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
2BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
3BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
4BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
5BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR

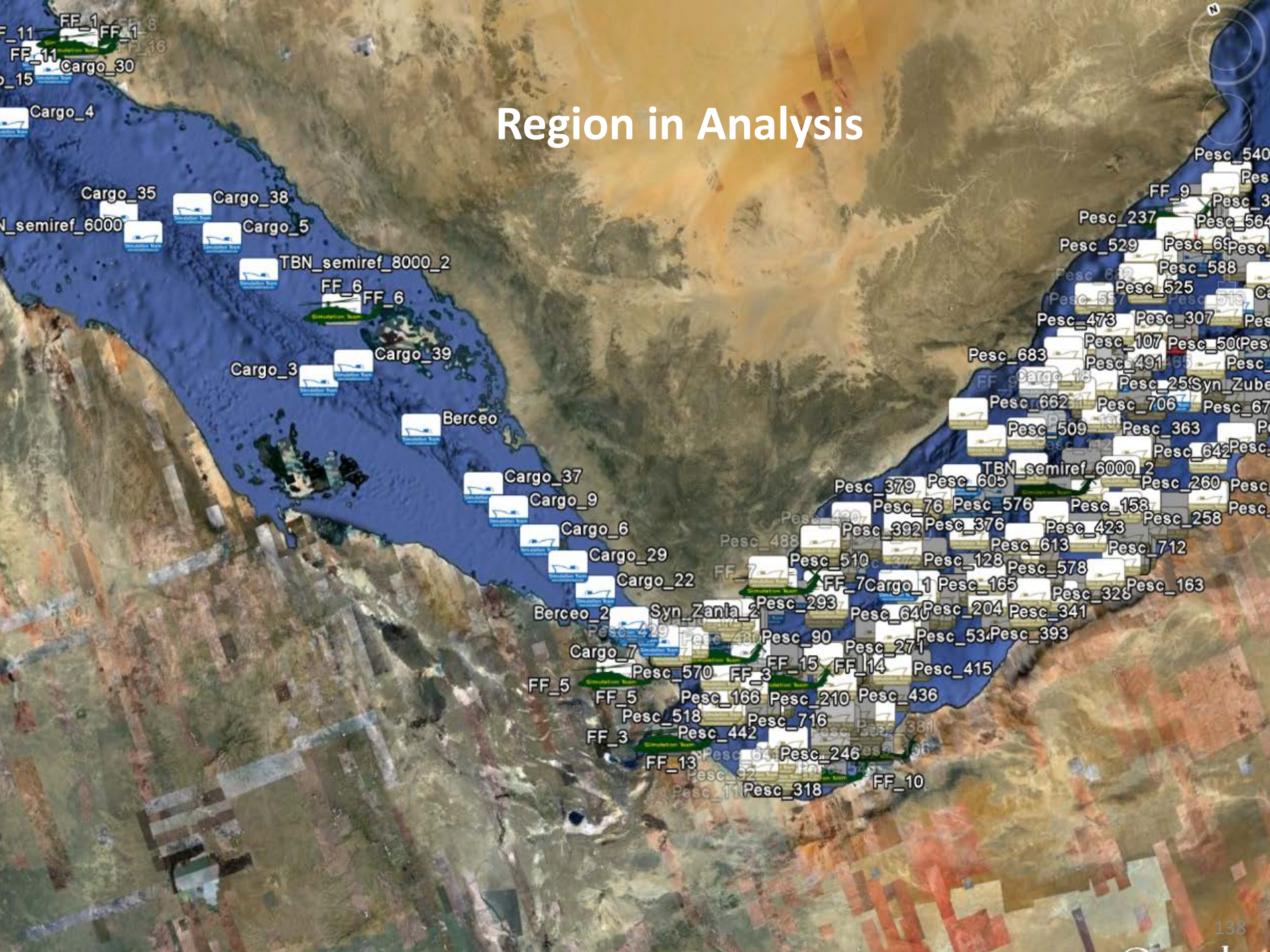

Collaborative C2 Approach
Bde HQ
Control of AH, AS90, GMLRS & Fast Jet support
1BG HQ
2BG HQ
3BG HQ
4BG HQ
5BG HQ
Fully connected BG (not all links shown)
Single Joint AoR

PANOPEA

***P**iracy **A**symmetric **N**aval **O**peration*
***P**atterns modeling for **E**ducation & **A**nalysis*

- PANOPEA is a simulator for reproduction of anti-piracy operations and for evaluating the different approaches defined in NEC C2M2
- PANOPEA reproduces military frigates and helicopters, ground base, cargos, fisherman, yachts traffic and pirates
- Units are managed by intelligent software agents




Region in Analysis
Cargo_30
Cargo_4
Cargo_35
Cargo_38
Cargo_5
TBN_semiref_8000_2
FF_6
Cargo_39
Cargo_3
Berceo
Cargo_37
Cargo_9
Cargo_6
Cargo_29
Cargo_22
Berceo_2
Syn_Zania_2
Cargo_7
FF_5
FF_3
FF_13
Pesc_318
FF_10
FF_9
Pesc_237
Pesc_529
Pesc_588
Pesc_525
Pesc_473
Pesc_307
Pesc_107
Pesc_683
Pesc_491
Pesc_662
Pesc_706
Pesc_509
Pesc_363
Pesc_642
TBN_semiref_6000_2
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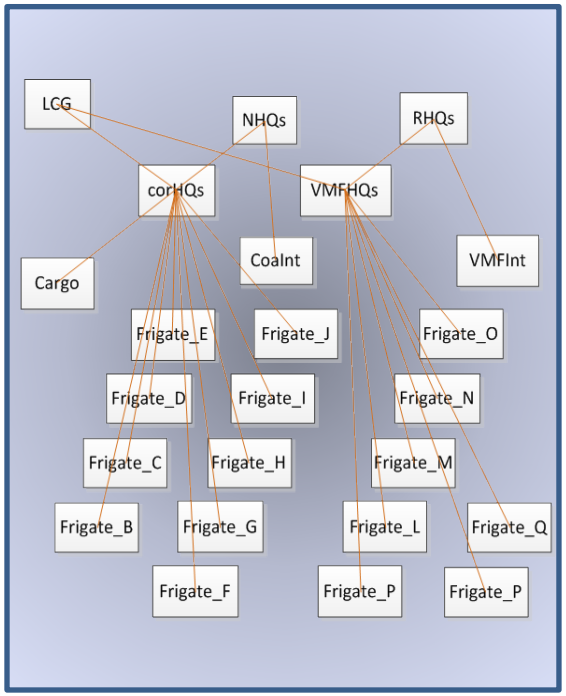
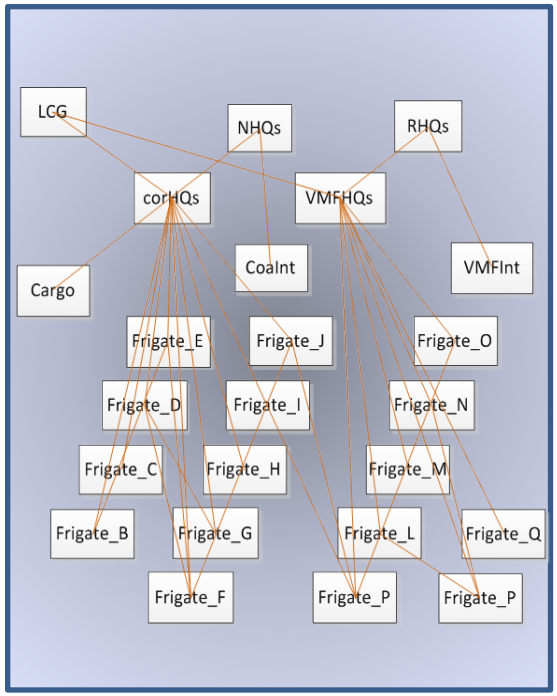
Pesc_260
Pesc_76
Pesc_576
Pesc_158
Pesc_258
Pesc_392
Pesc_376
Pesc_423
Pesc_613
Pesc_712
Pesc_510
Pesc_128
Pesc_578
FF_7
Cargo_1
Pesc_165
Pesc_163
Pesc_293
Pesc_328
Pesc_64
Pesc_204
Pesc_341
Pesc_90
Pesc_53
Pesc_393
Pesc_271
Pesc_570
FF_15
FF_14
Pesc_415
Pesc_166
Pesc_210
Pesc_436
Pesc_518
Pesc_716
Pesc_442
Pesc_246

PANOPEA

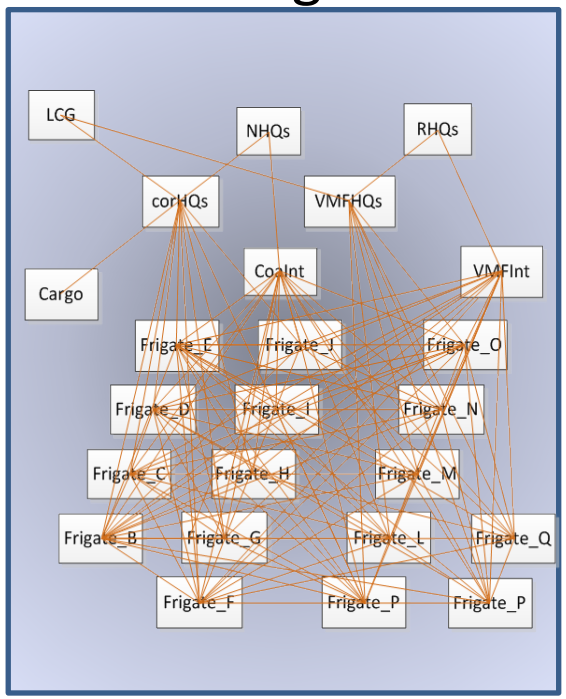
De-Conflicted



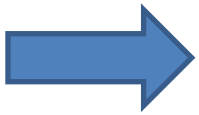
Collaborative



Edge



- Ship decision-making capability
- Intelligence DM capability
- Number of pirates
- Weather condition
- Misleading information



Endeavour Space

C2 Approaches Tested

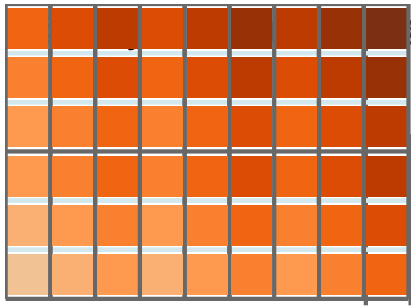
The differences among the experimental instantiations of the C2 approaches was investigated and these were found to be insignificant for the purposes of the CoE

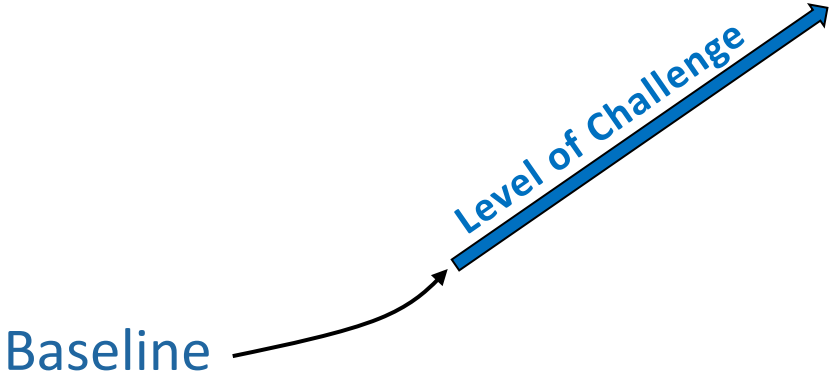
	ELICIT-IDA (USA)	ELICIT-TRUST (USA)	abELICIT (Portugal)	IMAGE (Canada)	WISE (UK)	PANOPEA (Italy)
Conflicted		X		X		
De-Conflicted	X	X		X	X	X
Coordinated	X	X	X	X		
Collaborative	X	X	X	X	X	X
Edge	X	X	X			X

Not all of the experiments implement all of the C2 Approaches

Creating an Endeavour Space

- The Endeavor Spaces were populated by combining all possible values of multiple variables, each one corresponding to an aspect of the situation
- Heat maps show the progressive degree of challenge of the Endeavour Spaces
  - Darker shades of orange represent most challenging circumstances
  - Values were normalized across the experiments





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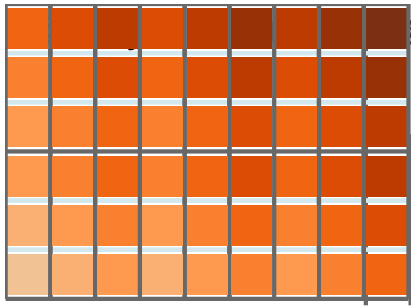
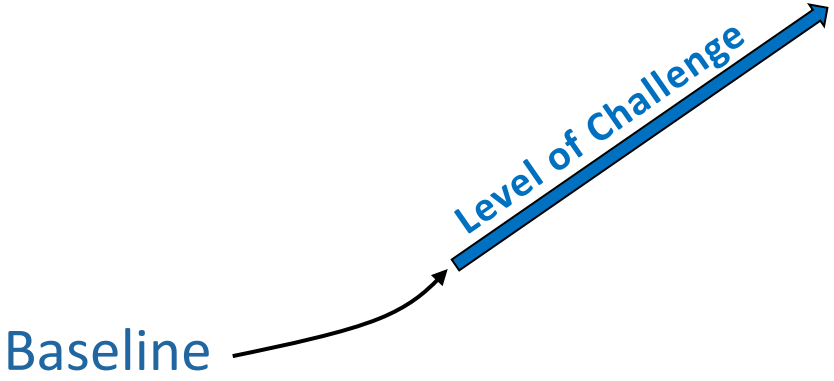
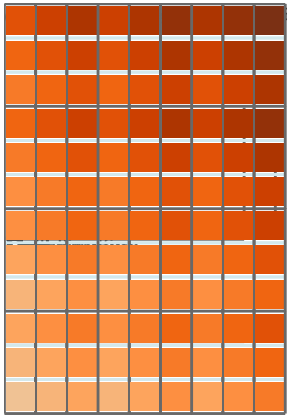


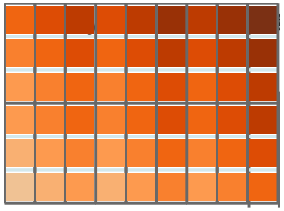


CoE Endeavour Spaces

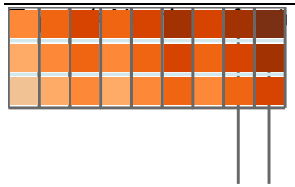
ELICIT-IDA



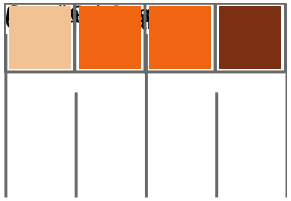
IMAGE



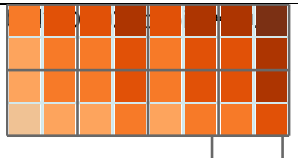
ELICIT-TRUST



WISE



PANOPEA



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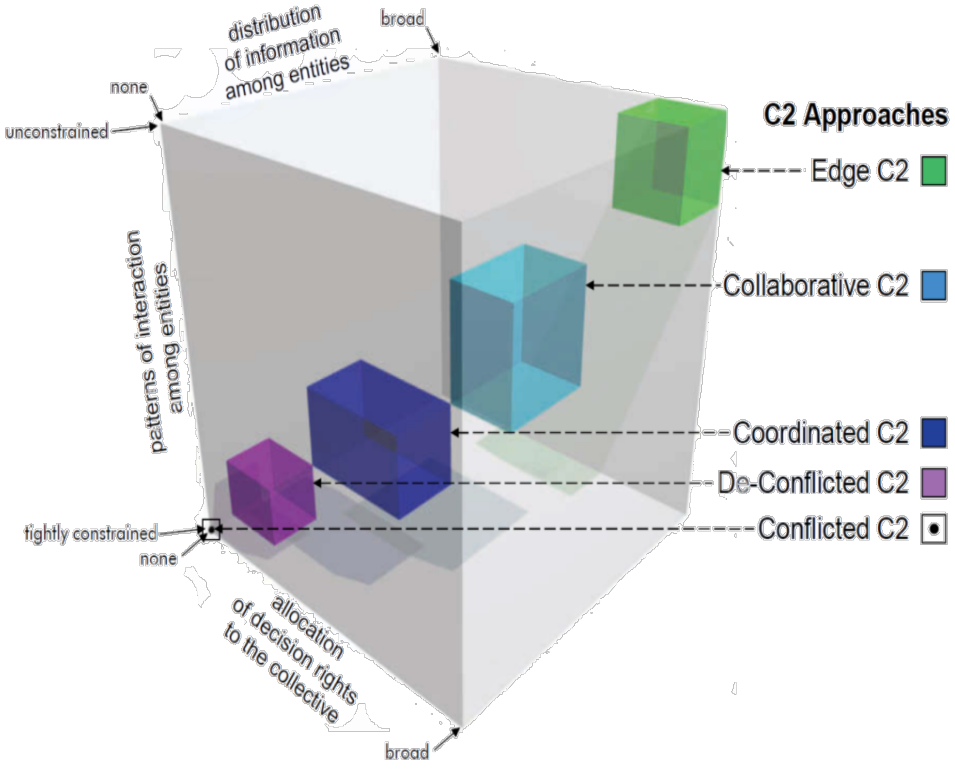
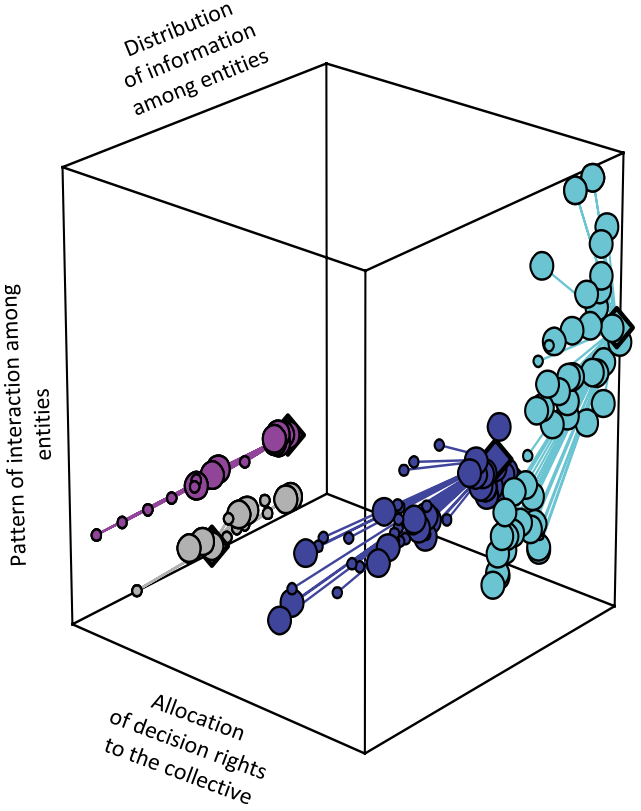
Approaches in the C2 Approach Space

H1: Each of the NATO C2 Maturity Model approaches is located in a distinct region of the C2 Approach Space

Theoretical Locations



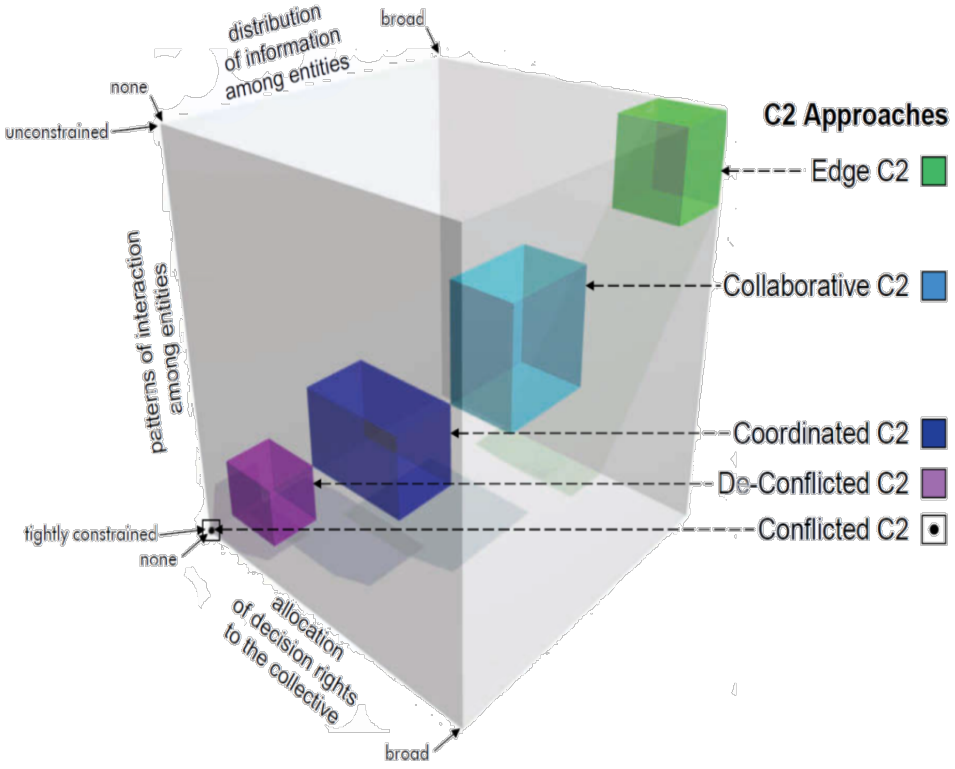
Measured Locations (IMAGE)



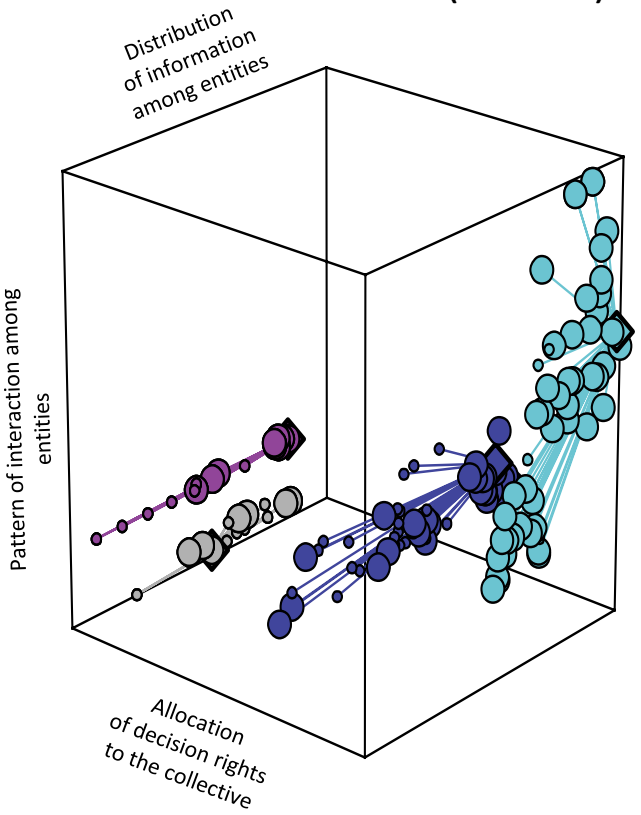
Approaches in the C2 Approach Space

H1: Each of the NATO C2 approaches is located in a distinct region of the C2 Approach Space

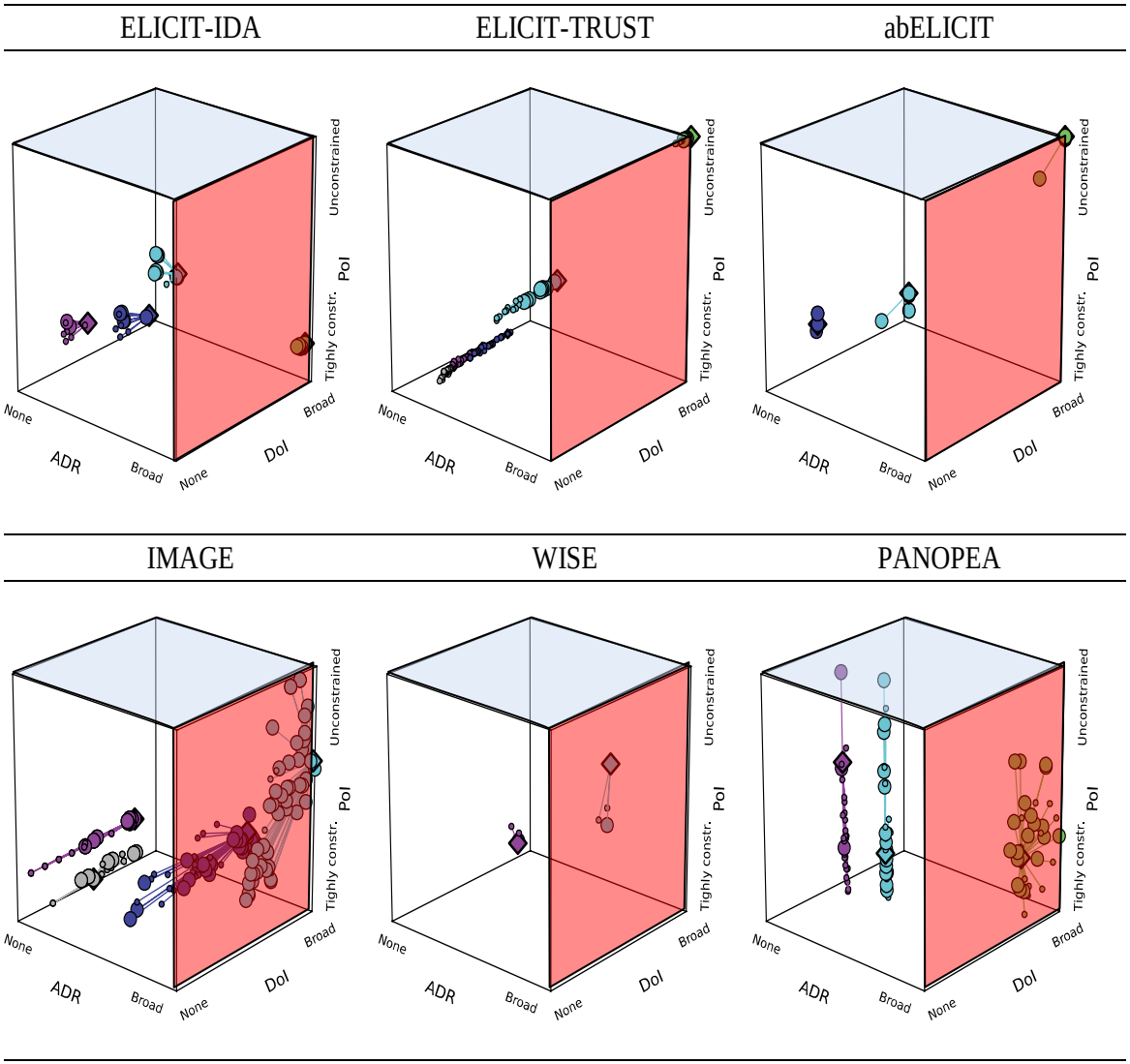
Theoretical Locations



Measured Locations (IMAGE)

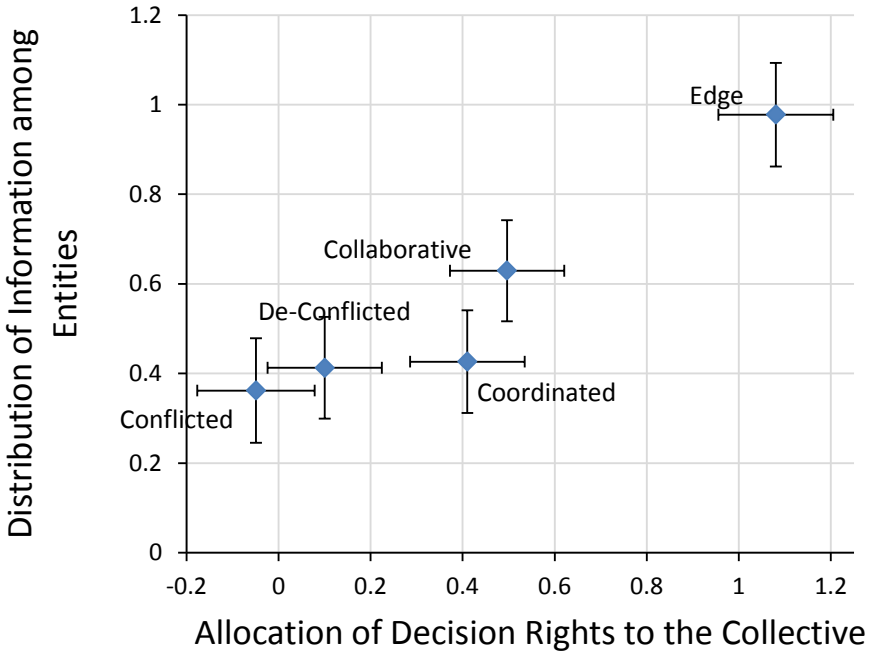


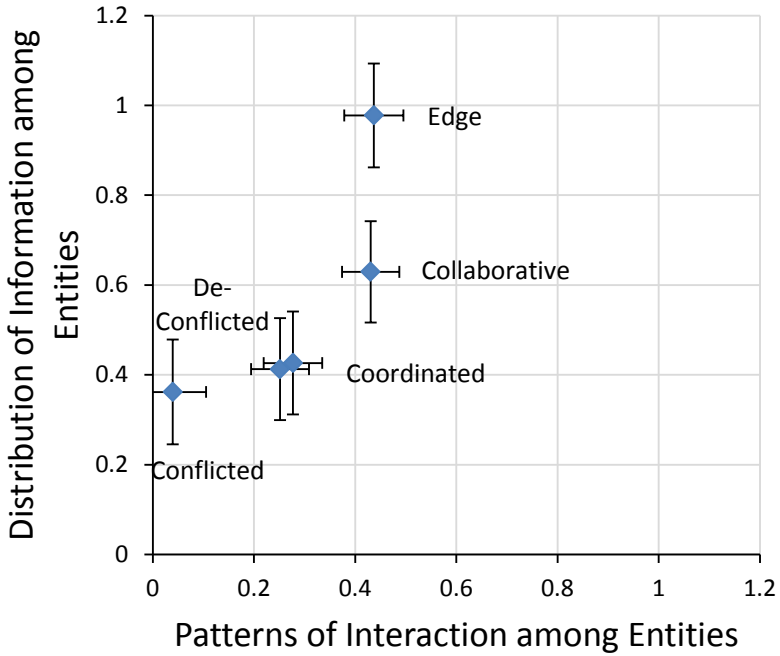
Approaches in the C2 Approach Space



C2 Approach Locations: Combined Results

95% confidence intervals

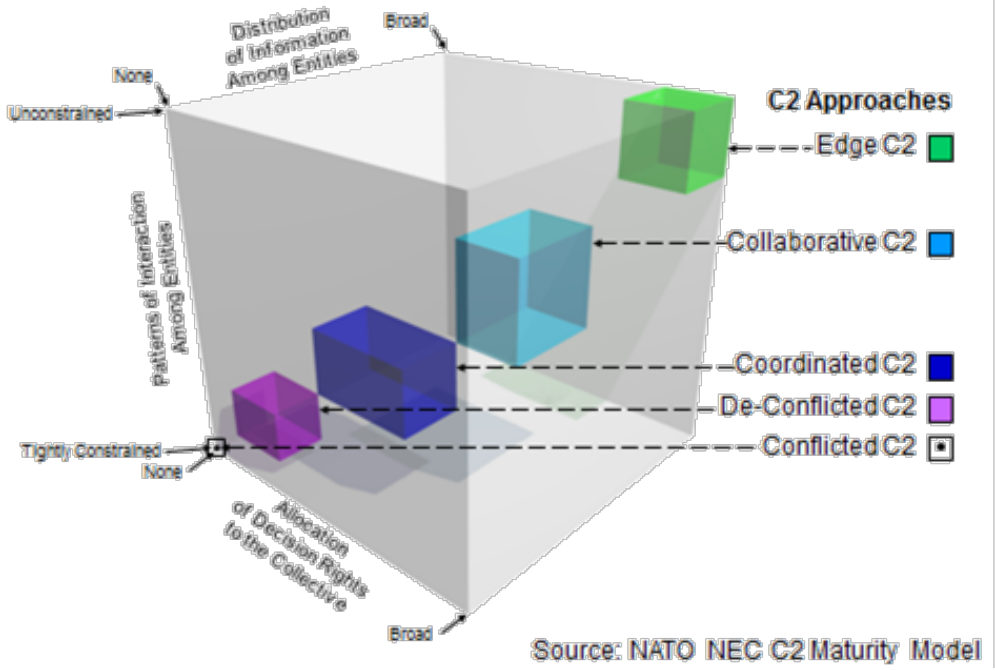




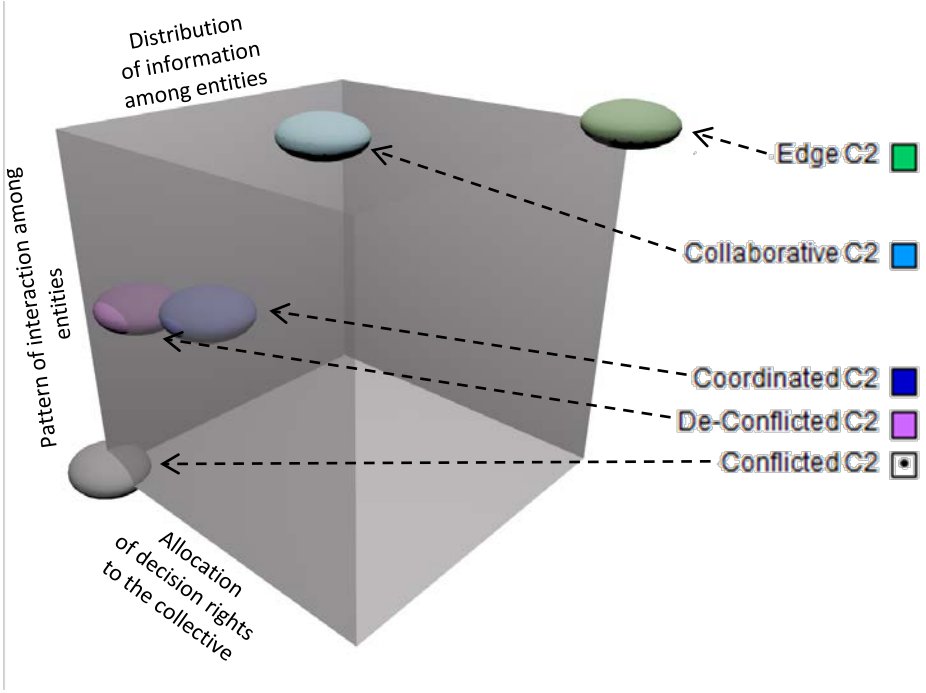
Combined results show that C2 approaches are located in distinct regions of the C2 Approach Space

C2 Approach Locations: Combined Results

Theoretical Model



Experimental Results

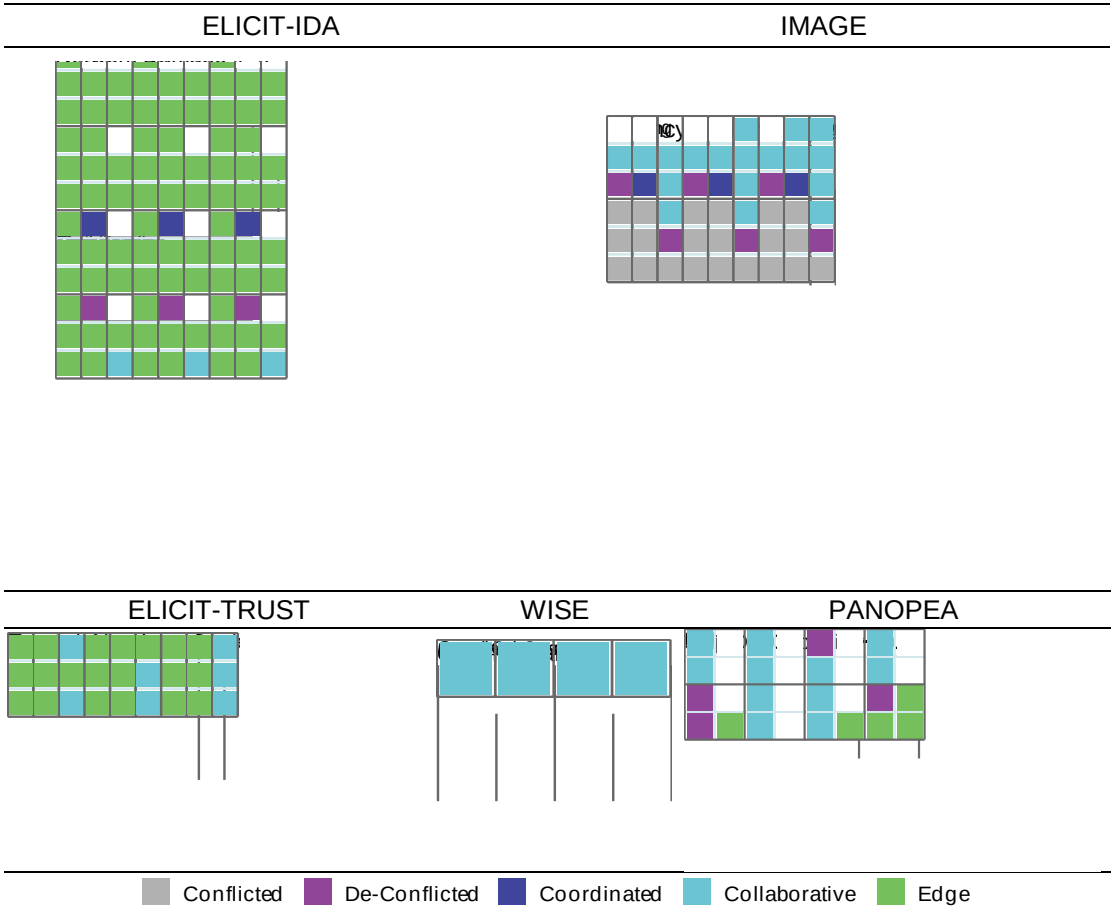


Combined results show that C2 approaches are located in distinct regions of the C2 Approach Space

No 'One Size' Fits All

H2: No one approach to C2 is always the most appropriate

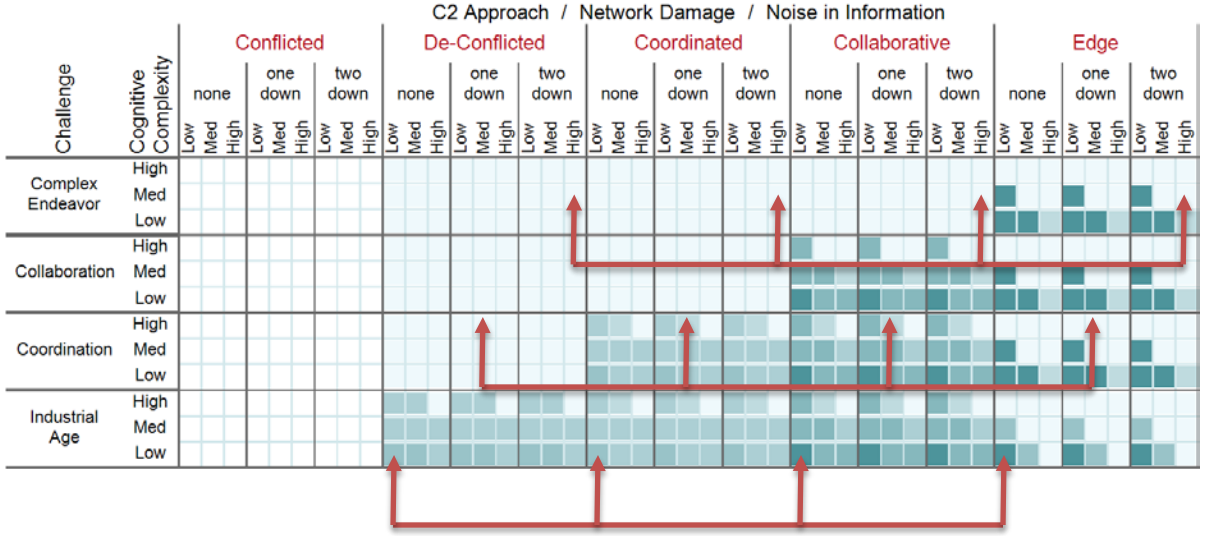
H3: More network-enabled approaches to C2 are more appropriate for more challenging circumstances; however, less network-enabled C2 approaches to C2 are more appropriate for some circumstances



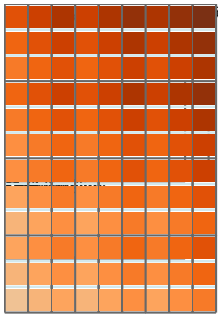
More Network-Enabled = More Agility

H4: More network-enabled approaches to C2 are more agile

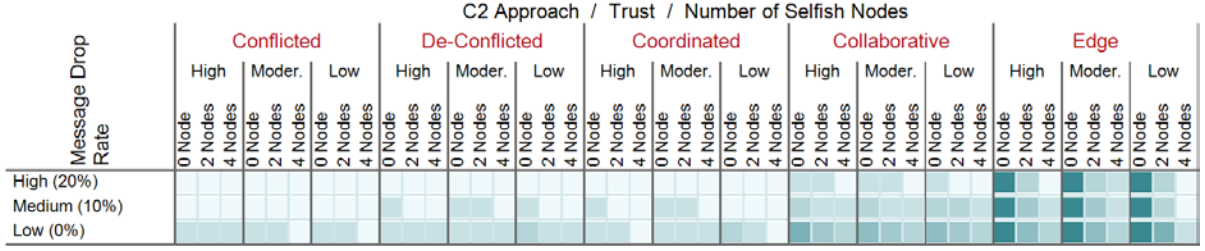
ELICIT-IDA



Same circumstance tested un different C2 Approaches



ELICIT-TRUST

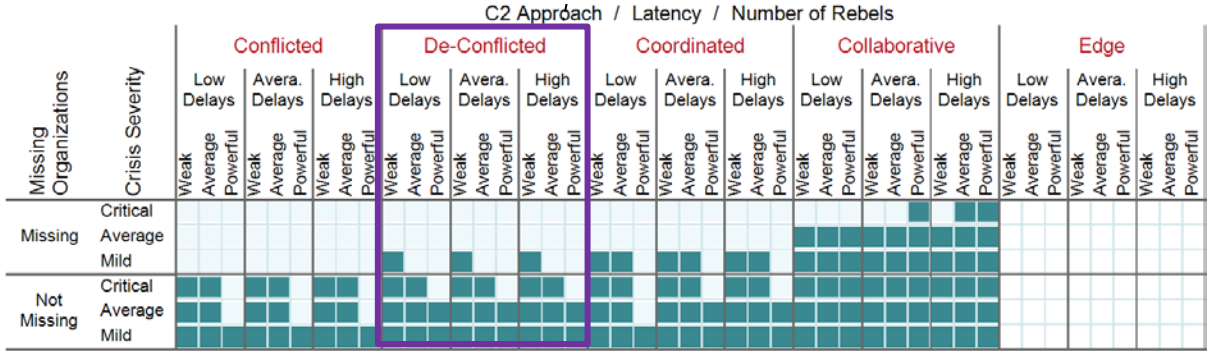


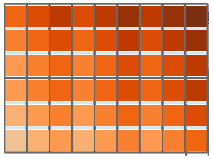
- Darker shades of teal correspond to higher levels of mission success (1), lighter ones to failure (0)
- Blank squares represent non-simulated cases

More Network-Enabled = More Agility

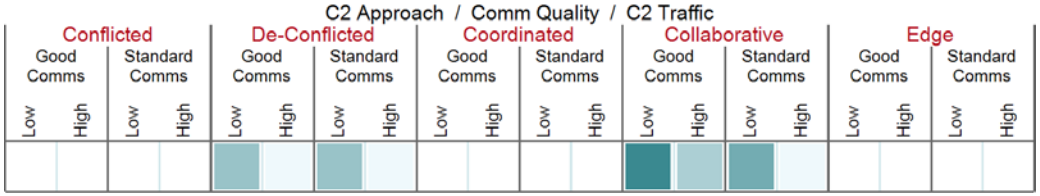
De-Conflicted was successful in 27 out of 54 circumstances
Agility Score (IMAGE, De-Conflicted) = 27/54 = 0.50

IMAGE

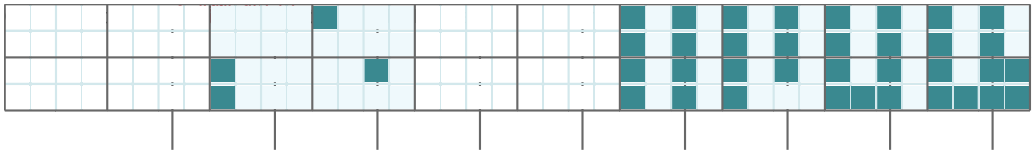




WISE



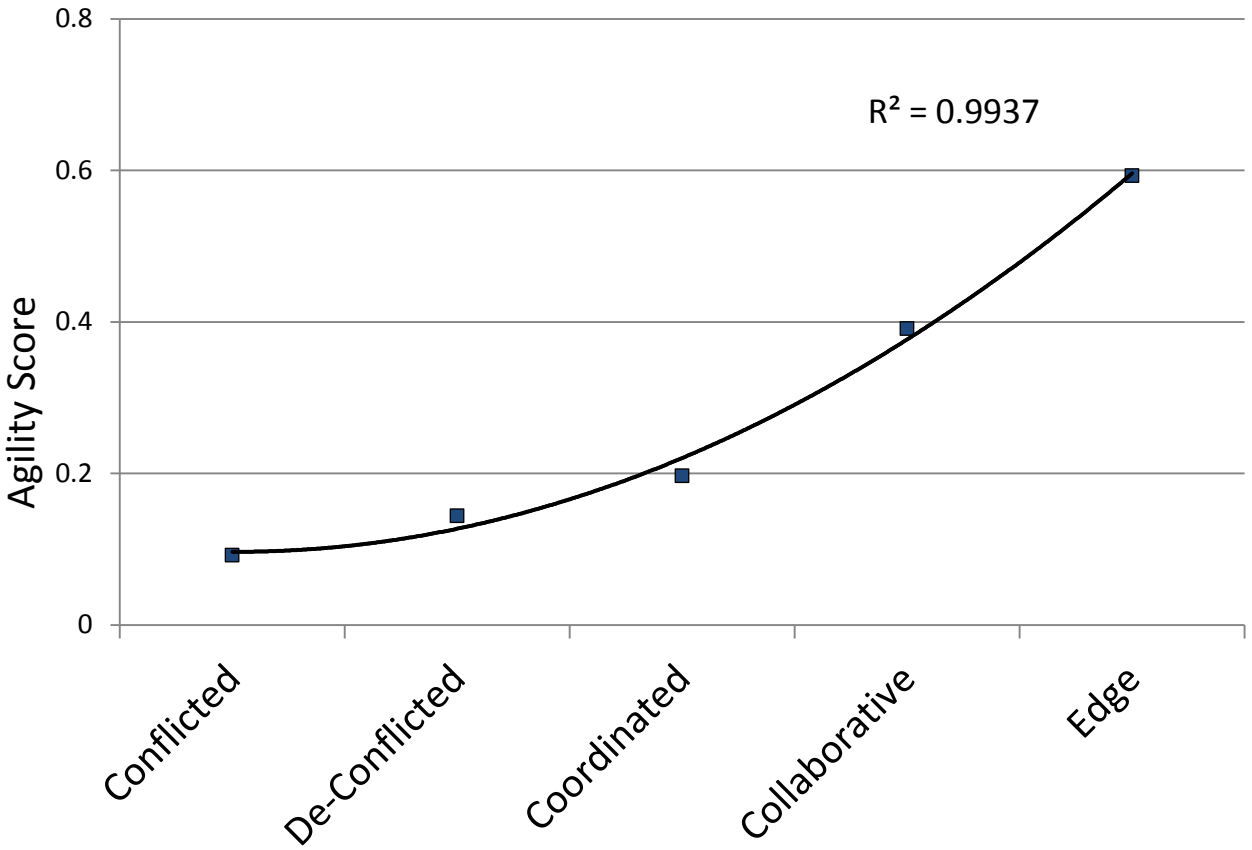
PANOPEA



- Darker shades of teal correspond to higher levels of mission success (1.0), lighter ones to failure (0.0)
- Blank squares represent non-simulated cases

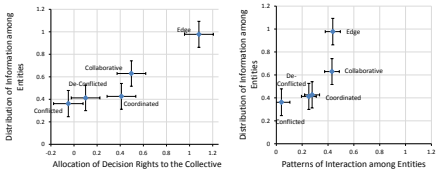
More Network-Enabled = More Agility

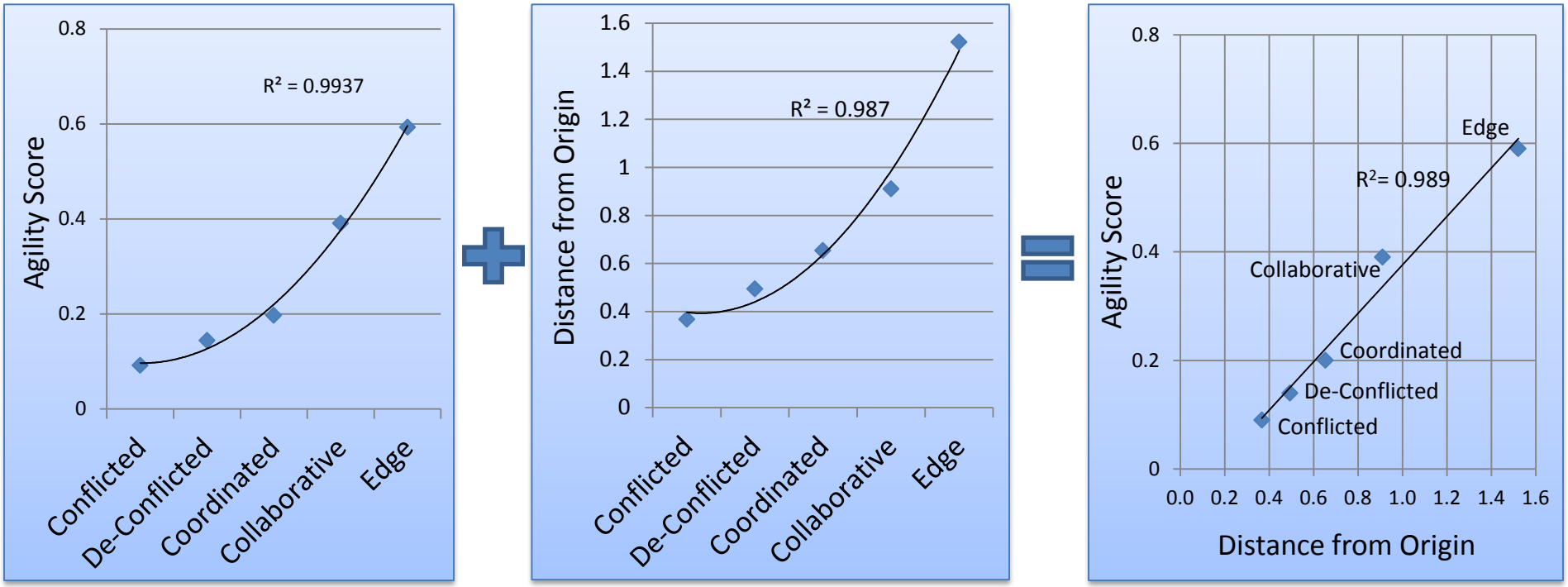
- Results suggest that Agility accelerates as C2 approaches become more network-enabled
- The relation between C2 Approach and Agility Score is quadratic ($R^2 = 0.99$)



More Network-Enabled = More Agility

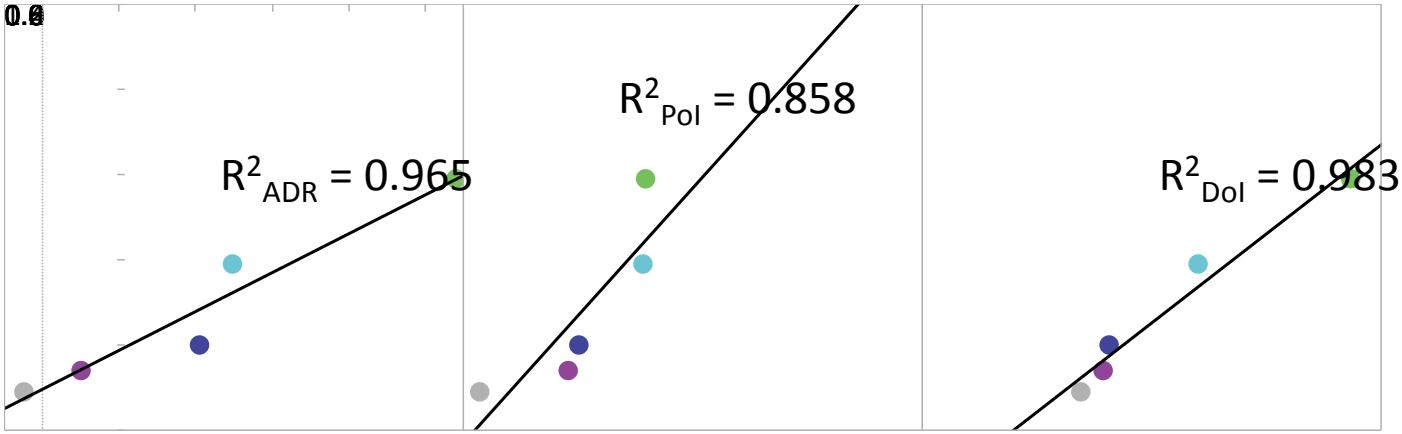
- There are a few possible explanations for the quadratic effect:
  - level of connectivity
  - position in the C2 Approach Space →





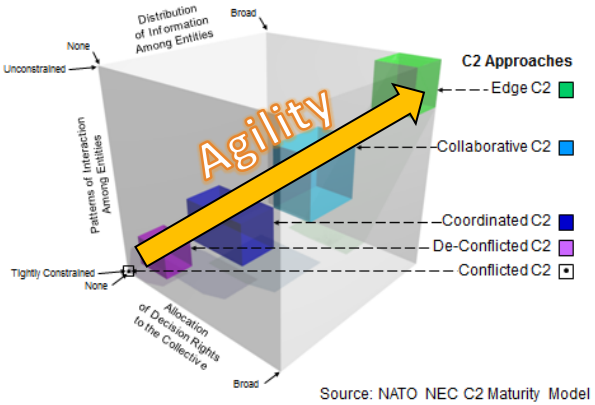
C2 Approach Space → Agility

H5: The dimensions of the C2 Approach Space are positively correlated with agility



- Individually: Agility Score is strongly correlated to each dimension of the C2 Approach Space
- Collectively (multiple regression):

Agility Score = 0.030 + 0.460 x Allocation of decision rights
– 0.269 x Patterns of interaction
+ 0.274 x Distribution of information

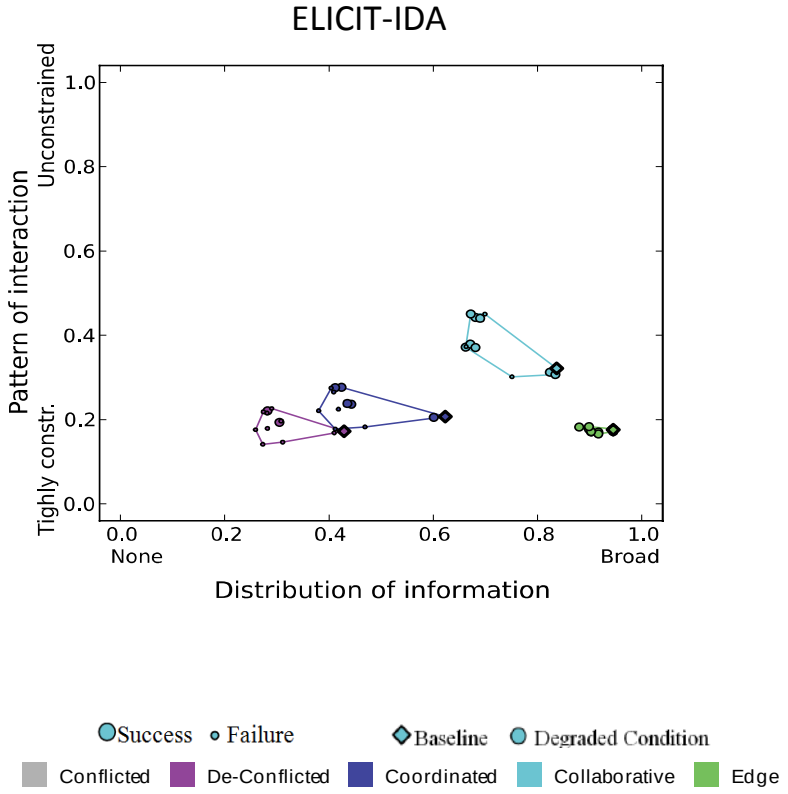


Source: NATO NEC C2 Maturity Model

Location Variations in C2 Approach Space

H6: More network-enabled C2 approaches are better able to maintain their position in the C2 Approach Space

- Only patterns of interaction and distribution of information were affected by circumstances
- The deviation was measured by the spreading, calculated from the area occupied by all circumstances



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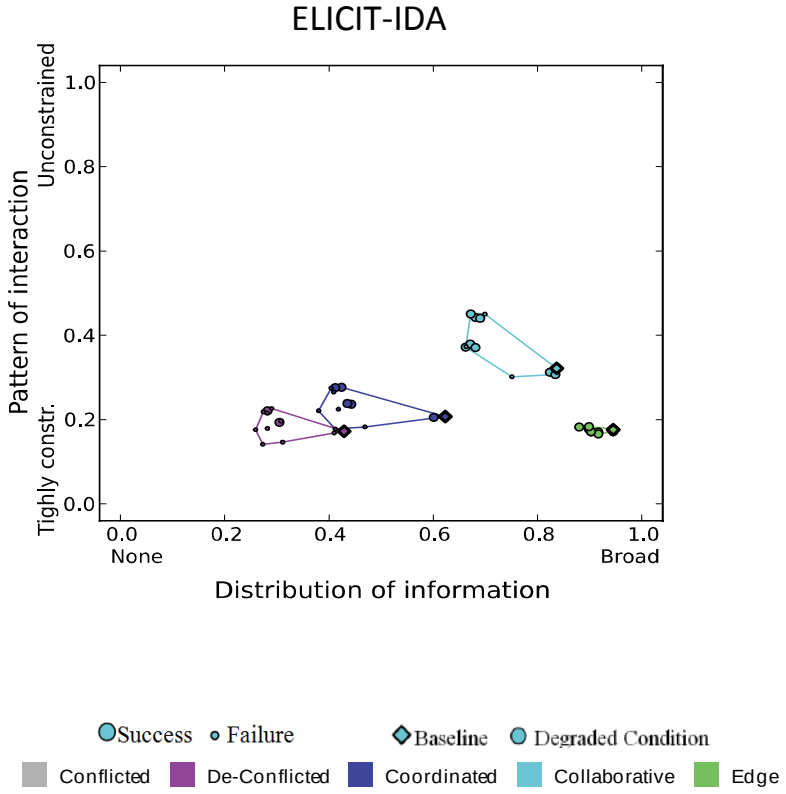

Location Variations in C2 Approach Space

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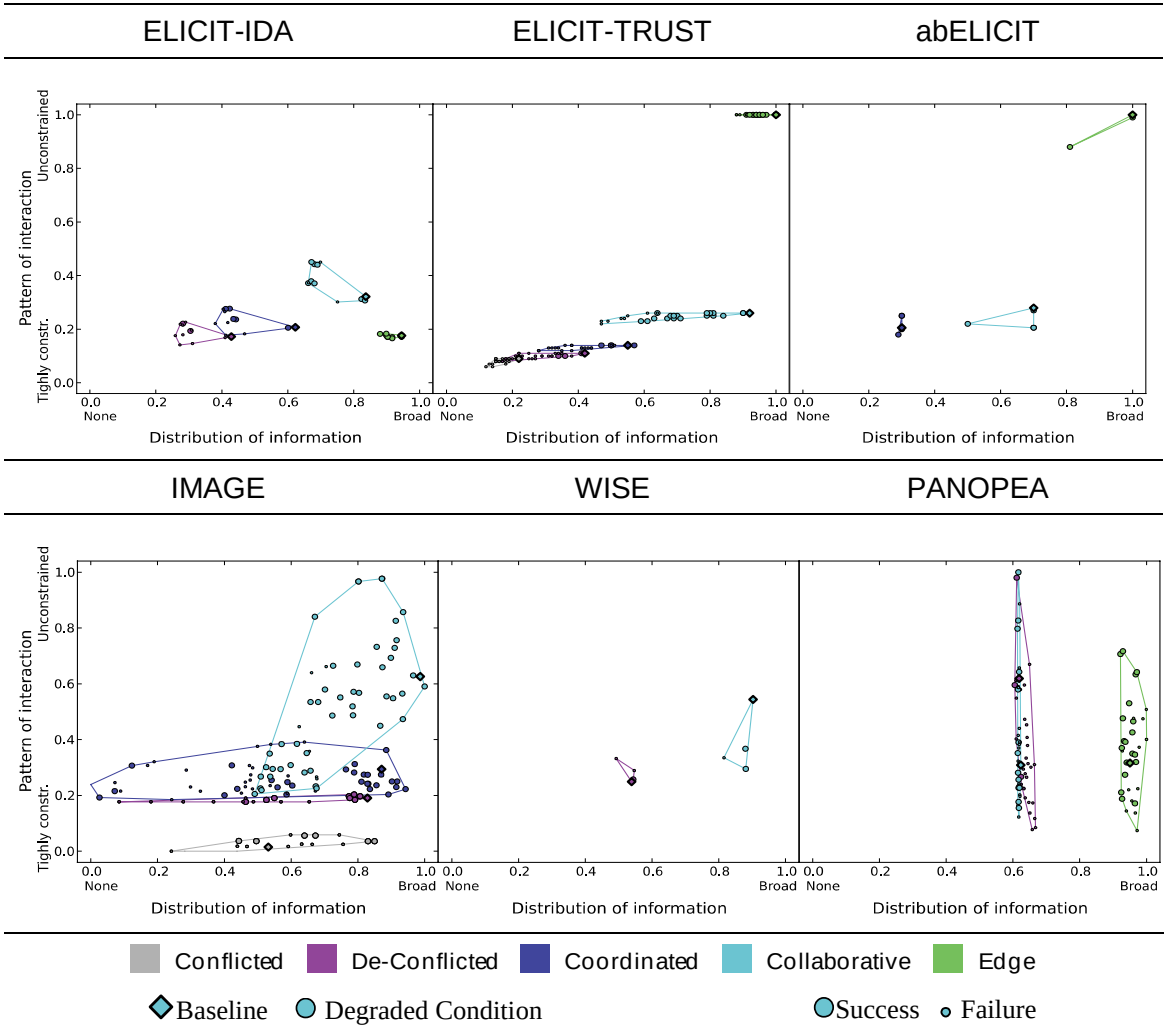
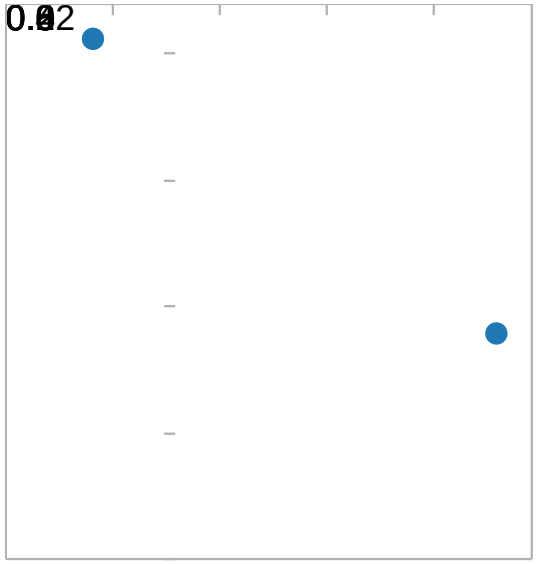


On vs. Off Diagonal

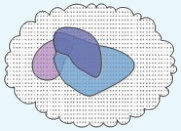
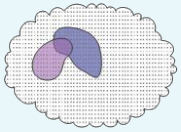
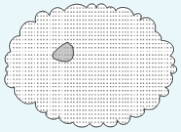
H7: On-diagonal (balanced) approaches to C2 are more agile



C2 Approach	On-Diagonal Group	Off-Diagonal Group
Average % Maximum Effectiveness	82%	36%
Average Distance from Diagonal	0.02	0.09

C2 Maturity → C2 Agility

H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted

C2 Maturity Levels	Contents of C2 Toolkit	C2 Approach Decision Requirement	Transition Requirements	Region of the Endeavor Space where a collective is successful
Level 5	Edge C2 Collaborative C2 Coordinated C2 De-Conflicted C2	Emergent	Edge C2 Collaborative C2 Coordinated C2 De-Conflicted C2	
Level 4	Collaborative C2 Coordinated C2 De-Conflicted C2	Recognize 3 situations and match to appropriate C2 approach	Collaborative C2 Coordinated C2 De-Conflicted C2	
Level 3	Coordinated C2 De-Conflicted C2	Recognize 2 situations and match to appropriate C2 approach	Coordinated C2 De-Conflicted C2	
Level 2	De-Conflicted C2	N/A	None	
Level 1	Conflicted C2	N/A	None	

Adapted from the Alberts, D.S. (2011). Agility Advantage, CCRP

Conflicted De-Conflicted Coordinated Collaborative Edge

C2 Maturity → C2 Agility

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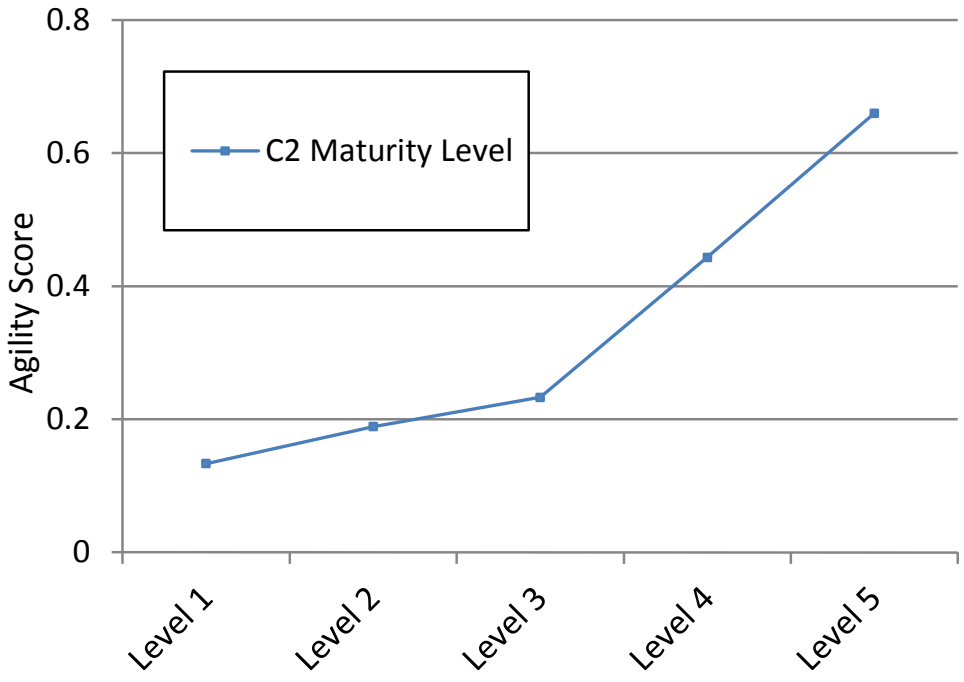
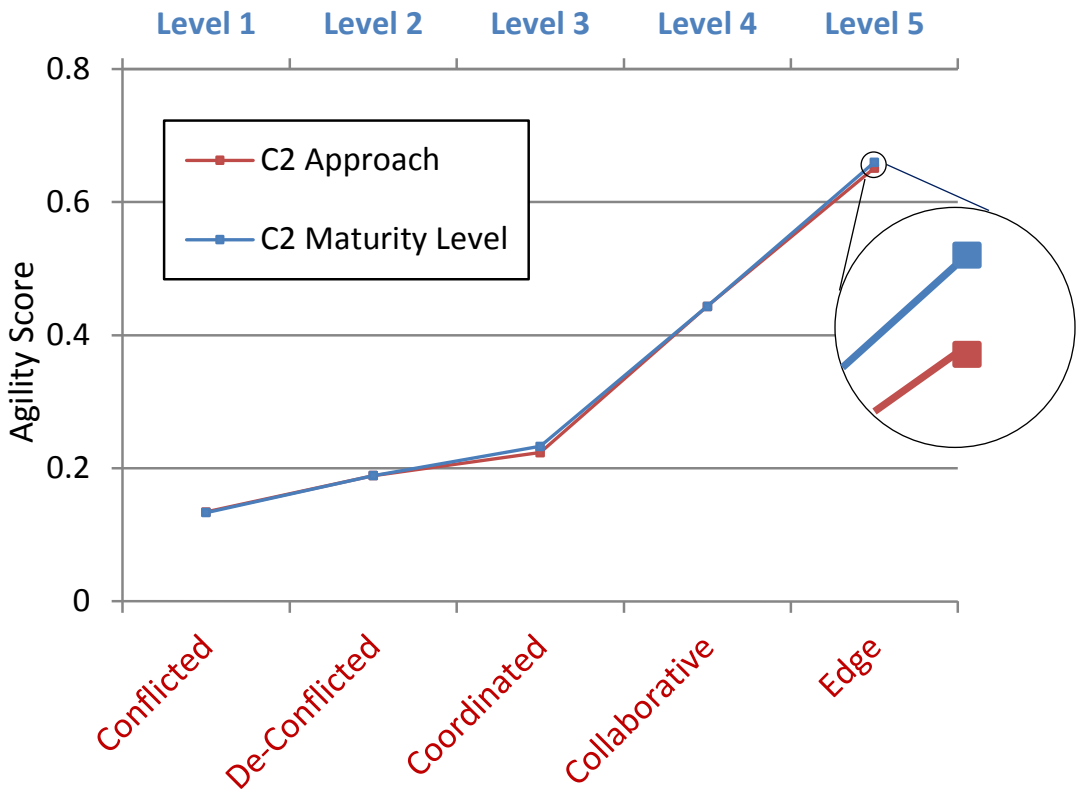
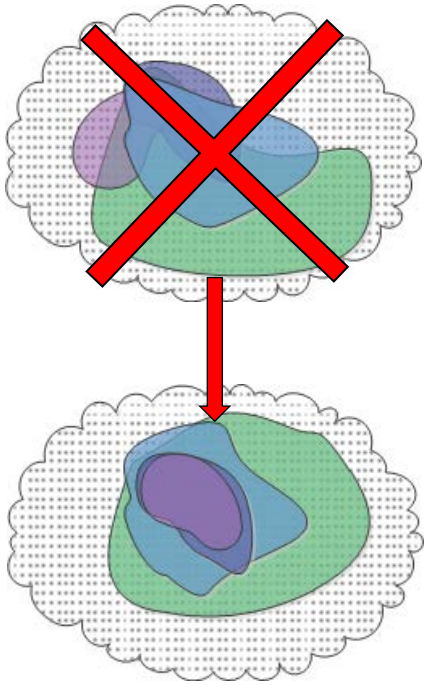


C2 Maturity → C2 Agility

Experimental results suggest more an imbricated model than a complementary one





Summary

Hypothesis	Results sustain the hypothesis?	Amount of evidences
H1: Each of the NATO C2 Maturity Model approaches (i.e., Conflicted, De-Conflicted, Co-ordinated, Collaborative, and Edge) is located in a distinct region of the C2 Approach Space	Yes	High
H2: No one C2 Approach to C2 is always to most appropriate	Yes	Medium
H3: More network-enabled Approaches to C2 are more appropriate for more challenging mission/circumstances, however less network-enabled C2 Approaches to C2 are more appropriate for some missions/circumstances	Yes	Medium
H4: More network-enabled approaches to C2 are more agile	Yes	High
H5: The dimensions of the C2 Approach Space are positively correlated with agility	Yes (2 out of 3)	Medium-High
H6: More network-enabled C2 Approaches are better able to maintain their position in the C2 Approach Space	No	None
H7: On-diagonal (balanced) approaches to C2 are more agile	Yes (ELICIT-IDA)	Low
H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted	Yes	Low

CoE Interim Products

- Alberts, D. S., Bernier, F., Chan, K., & Manso, M. (2013). C2 Approaches: Looking for the "Sweet Spot." *Proceedings of the 18th ICCRTS*. Alexandria, VA, USA.
- Alberts, D.S., Manso, M. (2012). Operationalizing and Improving C2 Agility: Lessons from Experimentation. Proceedings of the 17th ICCRTS. Fairfax, Va, USA.
- Bernier, F., Alberts, D. S., & Manso, M. (2013). International Multi-Experimentation Analysis on C2 Agility. Proceedings of the 18th ICCRTS. Alexandria, VA, USA.
- Bernier, F., Alberts, D. S., & Pearce, P. (2013). Meta-Analysis of Multiple Simulation-Based Experiments. Proceedings of the 18th ICCRTS. Alexandria, VA, USA.
- Bernier, F., Chan, K., Alberts, D. S., & Pearce, P. (2013). Coping with Degraded or Denied Environments in the C2 Approach Space. Proceedings of the 18th ICCRTS. Alexandria, VA, USA.
- Bernier, F. (2012). Agility of C2 Approaches and Requisite Maturity in a Comprehensive Approach Context. Proceedings of the 17th ICCRTS. Fairfax, VA, USA.
- Bruzzone, A. G., Tremori, A., & Merkuryev, Y. (2011). Asymmetric Marine Warfare: PANOPEA a Piracy Simulator for Investigating New C2 Solutions. Proceeding of the SCM MEMTS Conference (p. 32). Saint-Petersburg, Russia.
- Chan, K. (2010). ELICIT Experiments and the Impact of Communication Networks on Decision-Making in Social Networks. Proceedings of the 5th Annual Network Science Workshop. West Point, NY, USA.
- Chan, K., & Adali, S. (2012). An agent based model for trust and information sharing in networked systems. Proceedings of the Cognitive Methods in Situation Awareness and Decision Support (CogSIMA) (pp. 88-95). New Orleans, LA, USA.
- Chan, K., Cho, J. H., & Adali, S. (2012). Composite Trust Model for an Information Sharing Scenario. Proceedings of the Ubiquitous Intelligence & Computing and 9th International Conference on Autonomic & Trusted Computing (UIC/ATC) (pp. 439-446). Fukuoka, Japan.
- Manso, M. (2012). N2C2M2 Validation using abELICIT: Design and Analysis of ELICIT runs using software agents. *Proceedings of the 18th ICCRTS*. Fairfax, VA, USA.
- *Tremori, A., Massei, M., Madeo, F., Reverberi, A., (under publication), Interoperable simulation for asymmetric threats in maritime scenarios: a case based on virtual simulation and Intelligent agents. International Journal of Simulation and Process Modelling (IJSPM).*

Discussion

Questions?

Comments?

Agenda

- Objectives
- Basics of Agility
- Evolution of Command and Control
- C2 Agility
- C2 Agility Hypotheses
- Validation Approach
- Case Studies
- Campaign of Experimentation
- Summary of Findings, Conclusions, and Way Ahead

General Findings

- We are confident the theory is sound and ready to be tested in the field
- Increased C2 Agility improves the likelihood of mission success in the cases studied and the experiments conducted
- An Entity's C2 Agility can be improved by being able to adopt more approaches
- The extent to which C2 Agility is required is a function of the complexity and dynamics of the set of potential mission challenges faced (Endeavour Space)
- The set of concepts we call C2 Agility are understandable
- C2 Agility and the key variables associated with it can be observed and measured in both experimental and real world settings

“So Whats” from Hypotheses (1)

- There is more than one approach to C2. Therefore, Commanders need to become aware of this fact and recognize how C2 is being approached (their position in the C2 Approach Space).
- Commanders should not assume that their current approach will always work.
- If an entity anticipates being involved in Complex Endeavors, then it should be prepared to adopt more network-enabled approaches.
- If one can only adopt a single approach to C2, then an entity should adopt the most network-enabled approach it can.

“So Whats” from Hypotheses (2)

- All operations are subjected to stresses that can impact C2-related behaviors. This result re-enforces the need for self-monitoring found in the case studies, so that Entities remain aware of where they are located in the C2 Approach Space and how their positions may be affected by stresses.
- There is a need to maintain balance between and among the dimensions of the C2 Approach Space.
- Entities need to not only think about how to select and adopt an approach to C2 but also how to transition from one approach to another.

Future Research

- We need more experimentation and analysis to mature the theory and move from theory to practice
  - We encourage others to replicate our case studies and experiments using their own environments and mission challenges
  - We invite interest parties to join the NATO SAS follow-on activities
- We need to develop a way of visualizing how an organization is functioning so we can quickly ascertain where one is located in the C2 approach Space
- We need to more work on observing the presence or absence of the enablers and their impact on outcomes.

Way Ahead: Short Term

- Increase awareness of the need for increased C2 Agility and the ways in which it can be improved
- Review current command and staff training and identify the changes needed to incorporate C2 Agility concepts
- Incorporate hands-on experience (e.g. serious games) in an effort to assess and improve team and/or individual agility
- Develop a set of dimensions for the Endeavor Space and instantiate for at least one military mission
- Identify the PMESII and Mission-related cost-benefit drivers related to developing improved agility and develop a way of looking at Agility's return on investment (RoI)

Way Ahead: Mid-Long Term

- Develop and deploy tools to help organizations improve their C2 Agility
- Assessments of current levels of C2 Agility in military organizations and their partners
- Improve understanding of Agility through an iterative process that involves lessons learned from operations, applied research, experimentation, and operational analysis.
- Identify vulnerabilities of C2 Approaches

Discussion

Questions?

Comments?

Thank you!