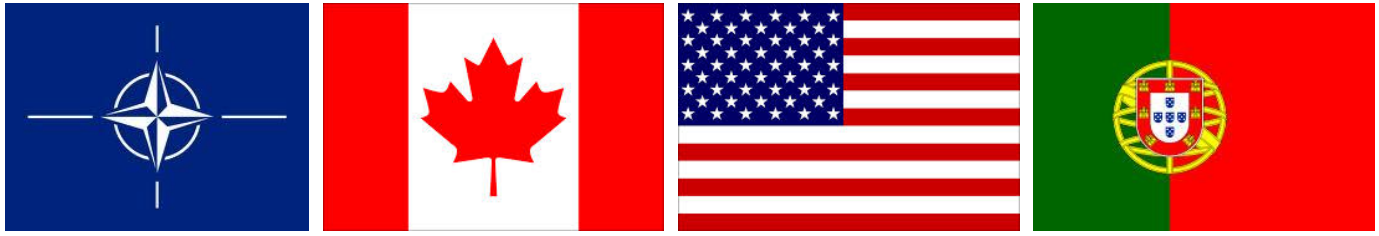

Paper ID: 015

International Multi-Experimentation Analysis on C2 Agility

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18th ICCRTS

C2 in Underdeveloped, Degraded and Denied Operational Environments

June 19-21, 2013 - IDA – Alexandria, Virginia, U.S.A.

Outline

- Background
- C2 Agility and Requisite Maturity
- SAS-085 Campaign of Experimentation
- Results on C2 Approach Agility
- Results on C2 Maneuver Agility
- Summary

Background

- Military missions are now characterized by uncertainty and include a wider spectrum of challenges than in the past
- These Complex Endeavors present a level of difficulty that is qualitatively different from traditional missions
- Previous C2 research and experience indicate that
  - the logical response to high degrees of uncertainty and complexity is to improve agility
  - effectiveness of a Complex Endeavor depends upon the appropriateness of the C2 Approach employed by the Collective

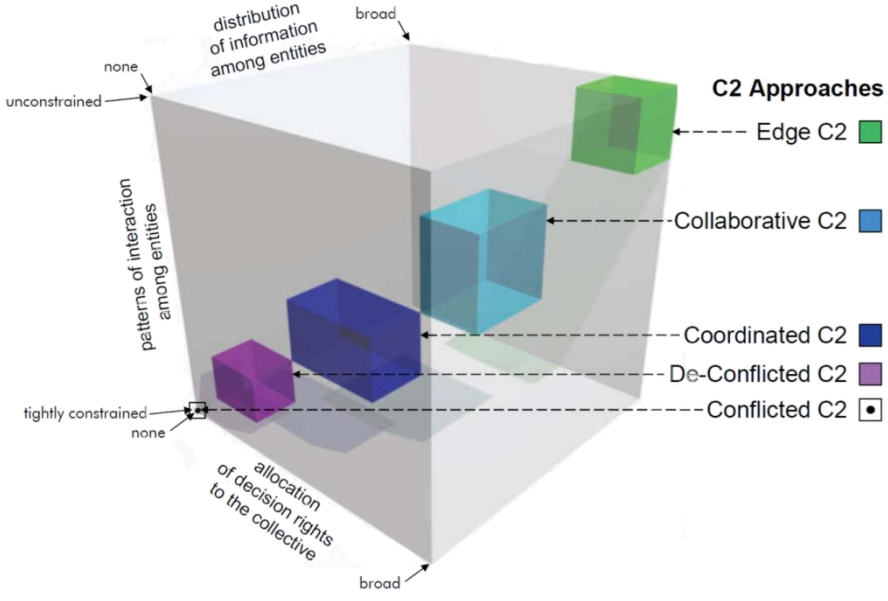
SAS-085 C2 Agility and Requisite Maturity

- SAS-085 on C2 Agility and Requisite Maturity aims to explore the concept of C2 Agility and provide answers to the following questions:
  - What do we mean by Agility / C2 Agility?
  - How can one measure Agility / C2 Agility?
  - To what extent is C2 Agility a requirement for Complex Endeavors / Enterprises?
  - What are the enablers / inhibitors of C2 Agility?
  - Are more networked enabled approaches to C2 more agile?
  - How can one move C2 Agility from a theory to become an institutionalized practice?

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

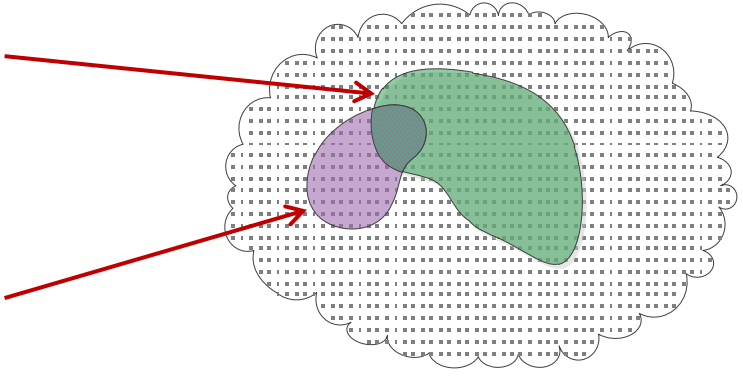
C2 Approach Space and Endeavour Space

C2 Approach Space



Source: NATO NEC C2 Maturity Model

Endeavor Space

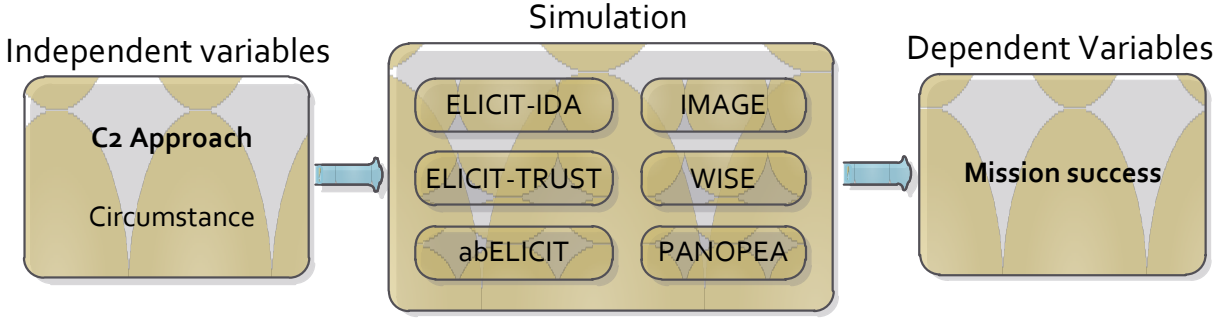


Definitions

- C2 Approach Agility is the ability of a collective operating according to a given C2 Approach to cope with a Complex Endeavor.
- C2 Maneuver Agility is the ability to adopt more than one C2 Approach
- C2 Agility combines both the agility provided by one or many C2 Approaches (would) and the ability to maneuver from one C2 Approach to another.

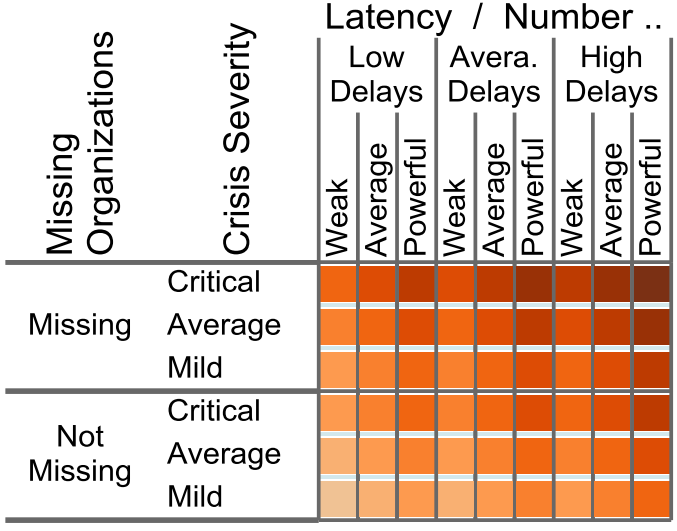
SAS-085 Campaign of Experimentation

- SAS-085 undertook a prospective meta-analysis based on a common high-level experimentation design utilizing multiple experimental platforms.
- This paper presents the results to two hypotheses
  - H1: Entities operating with more network-enabled C2 approaches exhibit more agility
  - H2: Entities that have a more mature C2 capability are potentially more agile



Endeavour Space and Degraded Conditions

- 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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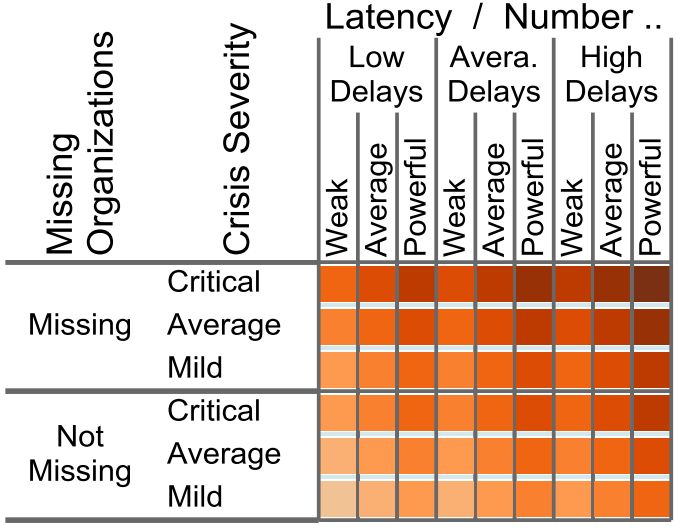

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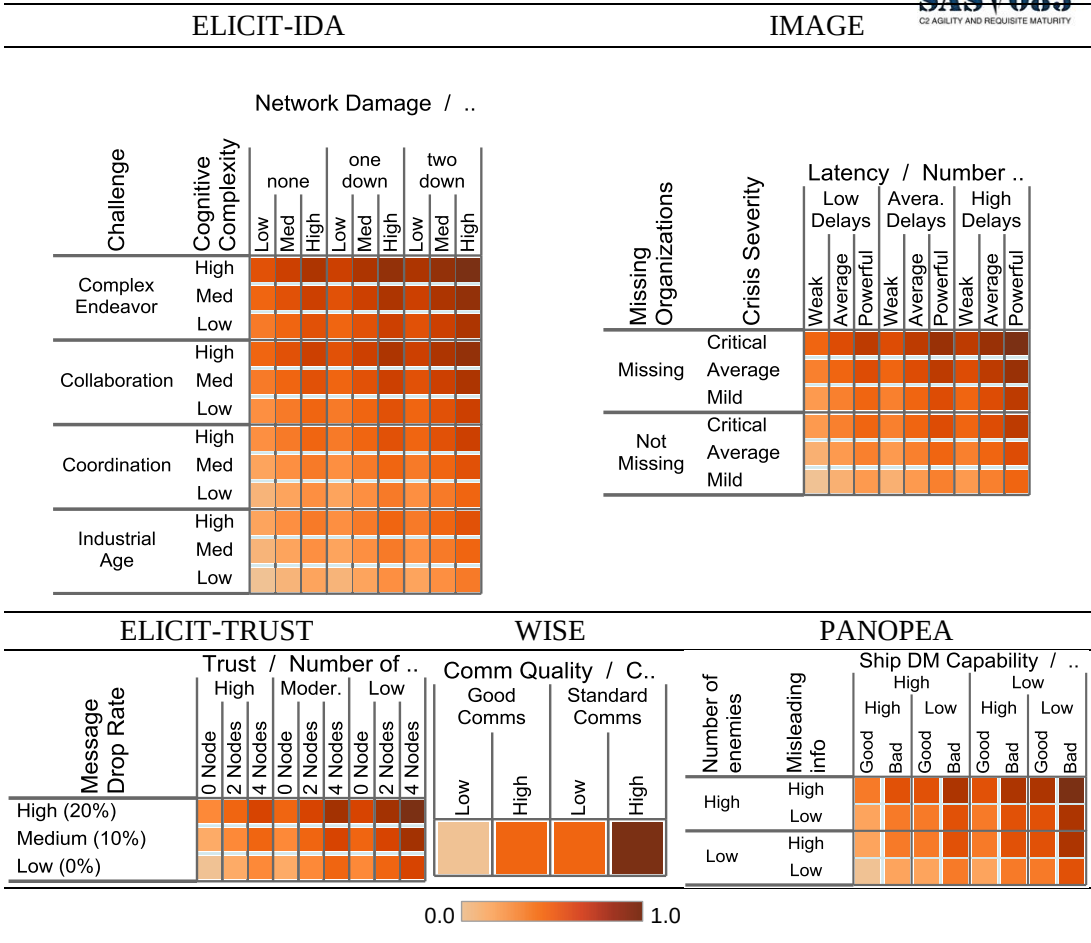
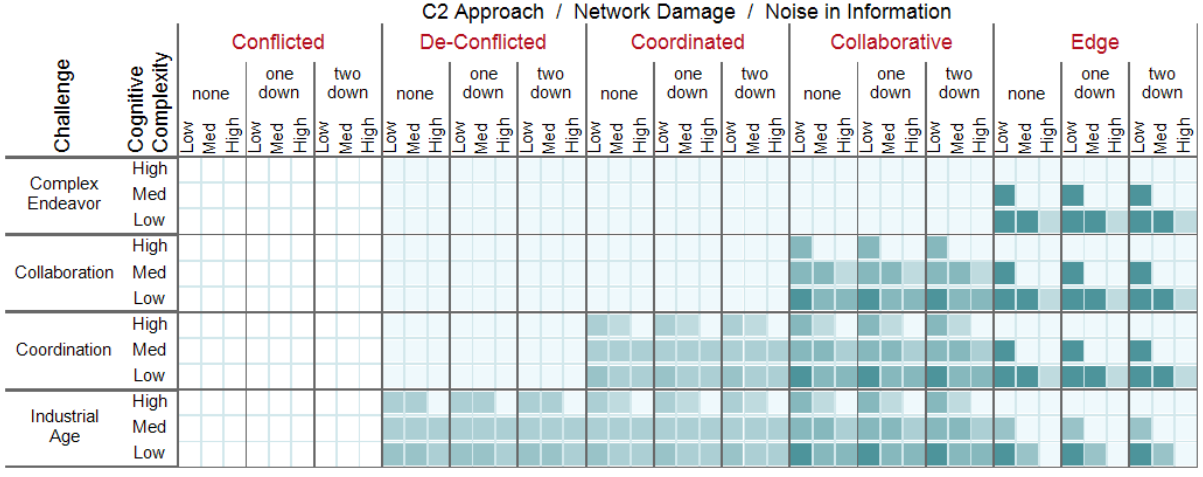
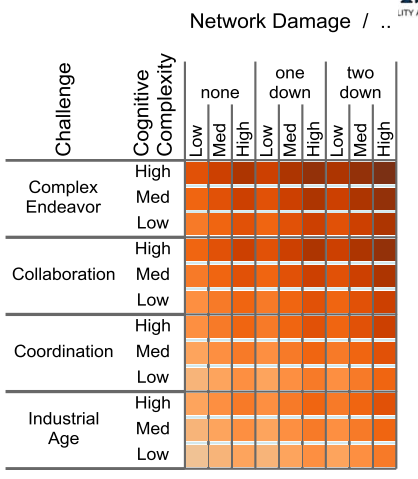


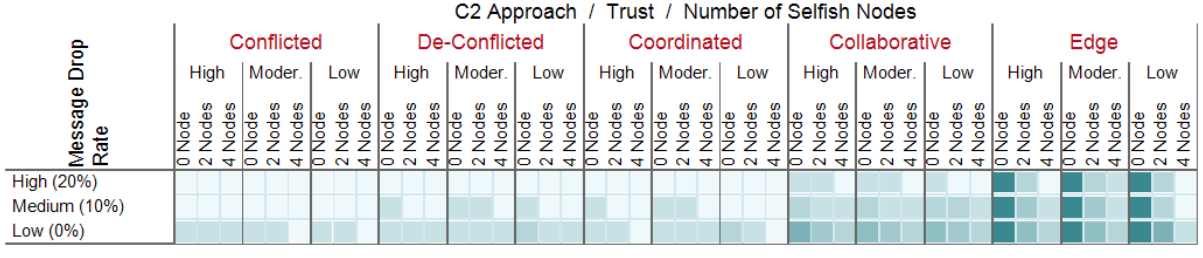
H1: Agility Maps

ELICIT-IDA





ELICIT-TRUST

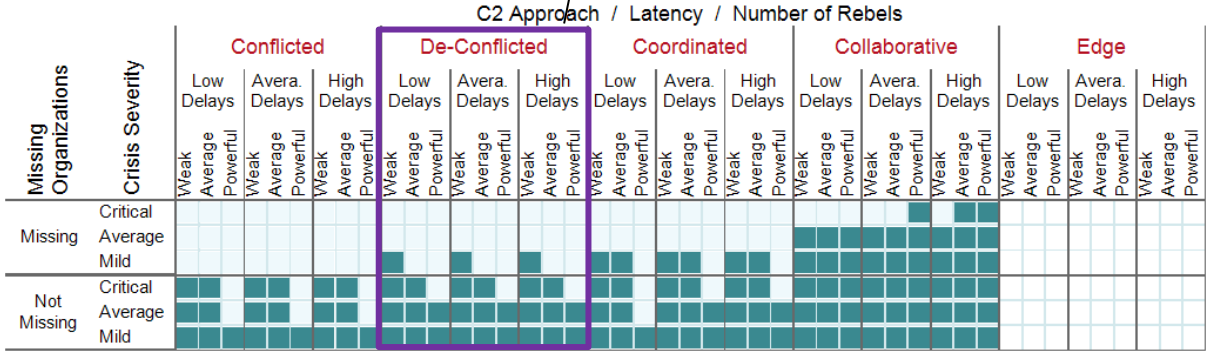


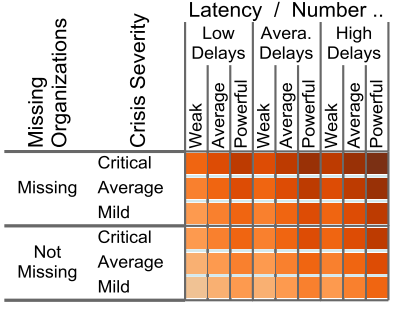
- Darker shades of teal correspond to higher levels of mission success (1.0), lighter ones to failure (0.0)
- Blank squares represent non-simulated cases

H1: Agility Maps

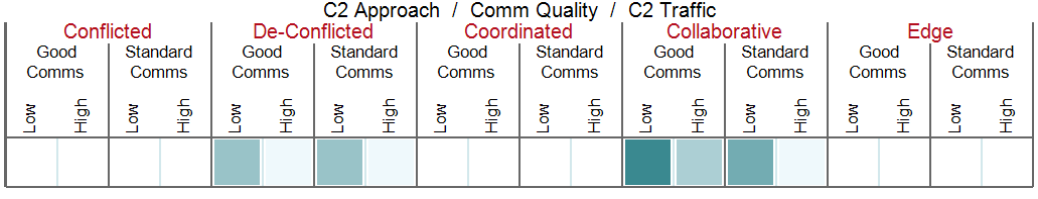
De-Conflicted was successful in 27 out of 54 circumstances
Agility Score (IMAGE, De-Conflicted) = 27/54 = 0.50

IMAGE

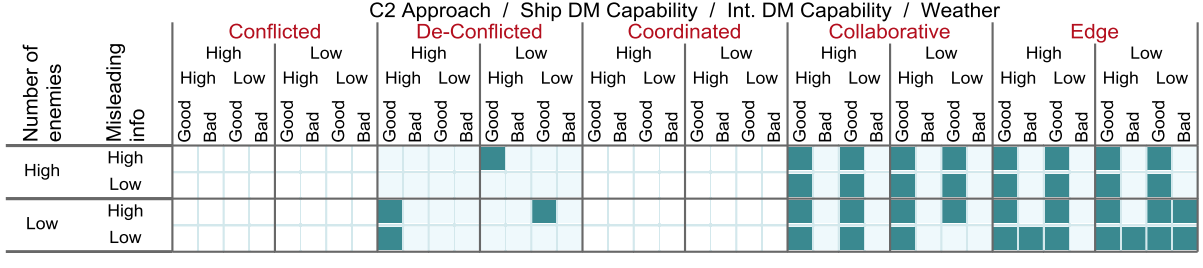




WISE



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

H1: Agility Scores

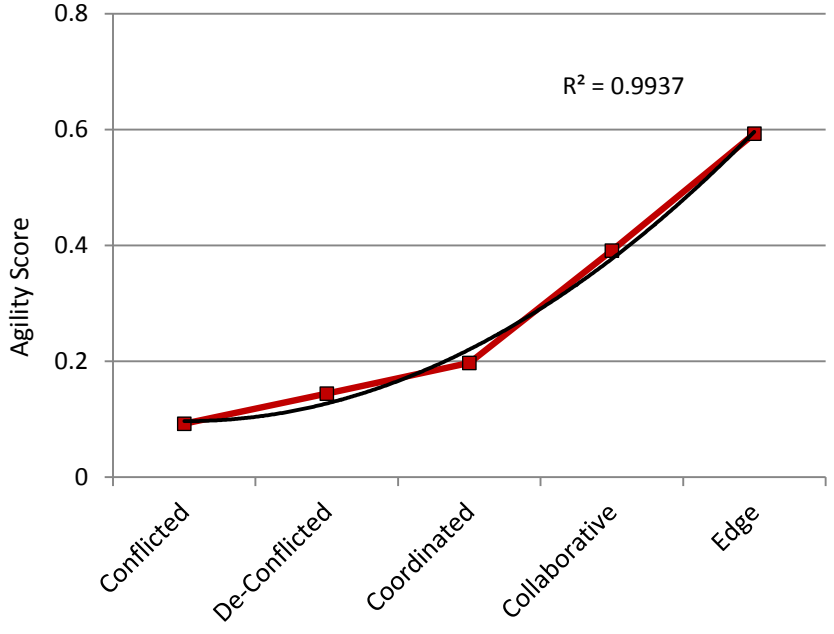
C2 Approach	ELICIT-IDA	ELICIT-TRUST	abELICIT	IMAGE	WISE	PANOPEA	LS-Mean (SE)
Conflicted		0.04		0.39			0.09 (0.10)
De-Conflicted	0.06	0.06		0.50	0.21	0.13	0.14 (0.09)
Coordinated	0.10	0.06	0.02	0.54			0.20 (0.09)
Collaborative	0.26	0.18	0.13	0.89	0.42	0.47	0.39 (0.09)
Edge	0.55	0.46	0.33			0.63	0.59 (0.09)

A

B

- Agility Score was computed for each experiment and C2 Approach (Agility Score represents the proportion of the endeavor space in which a collective is successful in a given C2 Approach)
- A statistical test revealed that Agility Score differed significantly across the five C2 Approaches, $F(4,11) = 30.68$, $p < 0.001$: $Agility_B > Agility_A$, $Agility_{Edge} > Agility_{Collaborative}$
- Results strongly support H1 : *Entities operating with more network-enabled C2 approaches exhibit more agility*

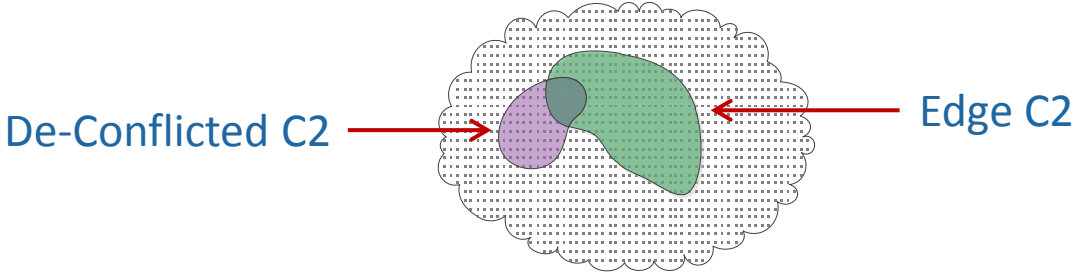
H1: Agility Scores



- Results suggest that agility benefits accelerate with more network-enabled C2 Approaches.
- The relation between C2 Approach and Agility Score is quadratic ($R^2 = 0.994$), suggesting an effect of the increased level of connectivity

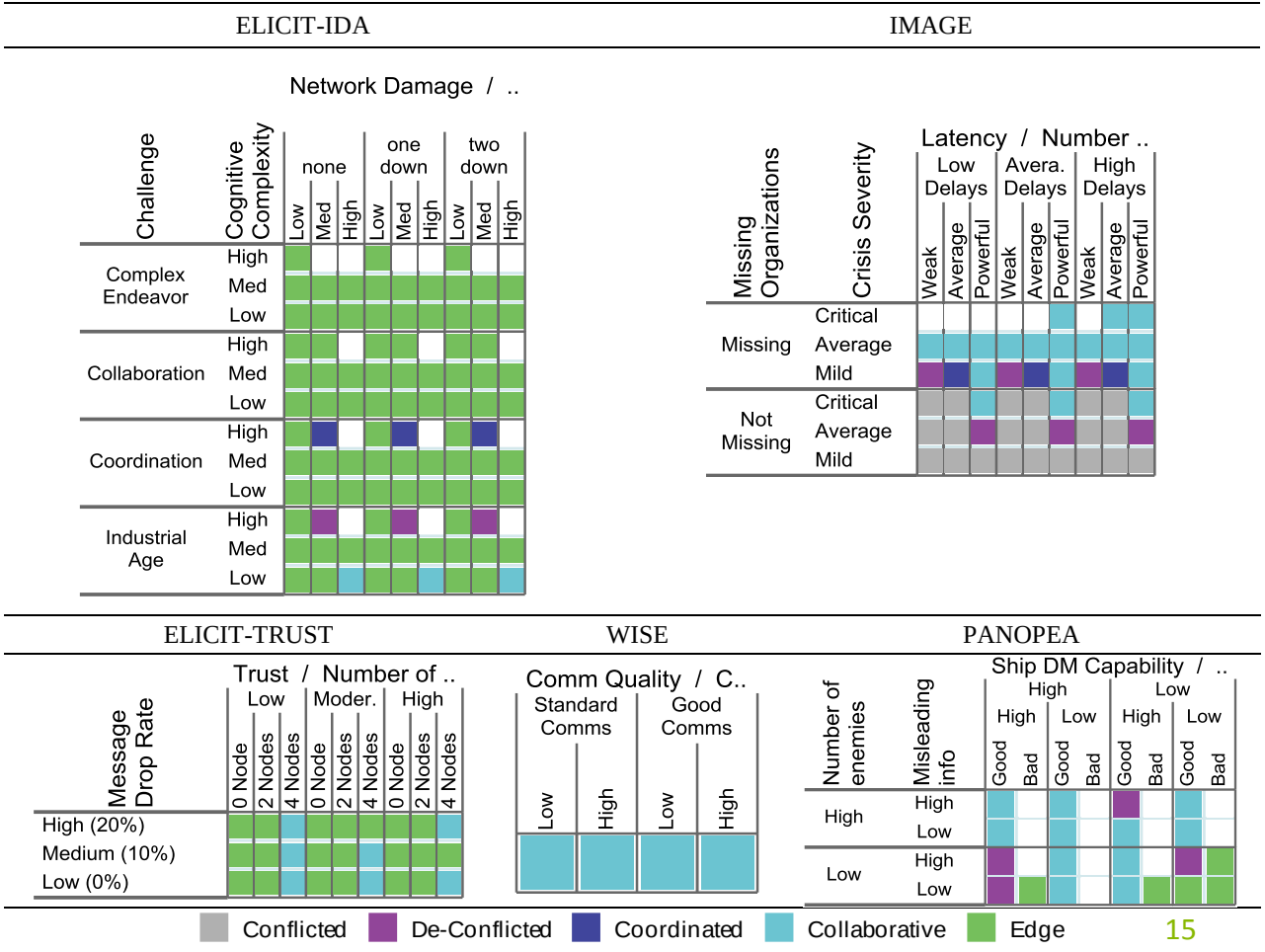
H2: Entities That Have a More Mature C2 Capability Are Potentially More Agile

- More network-enabled C2 Approaches are not always the best options:
  - In some situations, less network-enabled C2 Approaches can be just as affective or even the only one in ensuring success
  - Less network-enabled C2 Approaches can be preferred because of cost and time constraints or of practicality considerations
- Entities being able to adopt more than one C2 Approach should be successful in a greater portion of the Endeavour Space

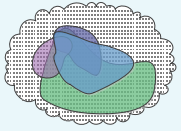


H2: Map of the Most Successful C2 Approach (optimistic)

- The most network-enabled C2 Approach was not the best C2 Approach for about 5% (pessimistic) to 35% (optimistic) of the Endeavour Space



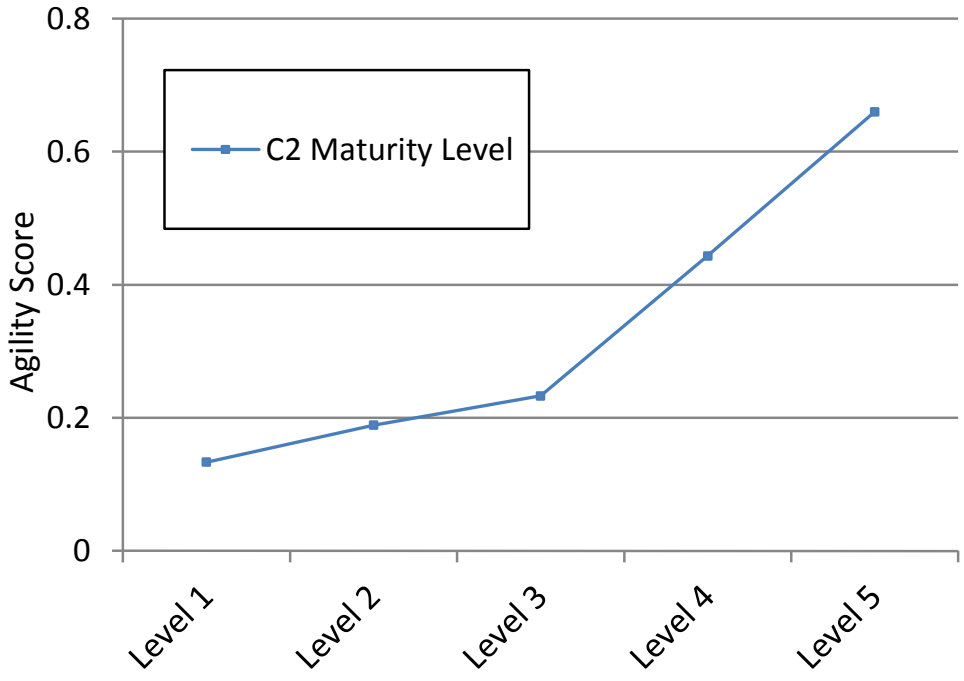
H2: C2 Agility and Requisite Maturity

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	

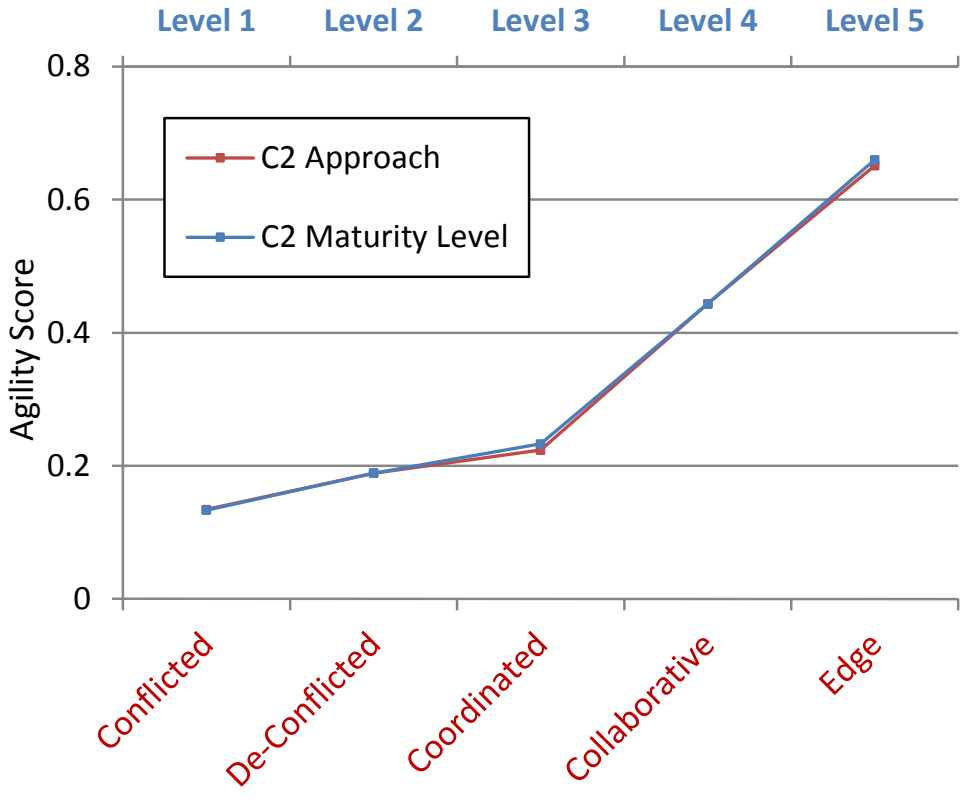
Adapted from the Alberts, S.D. (2011). Agility Advantage, CCRP

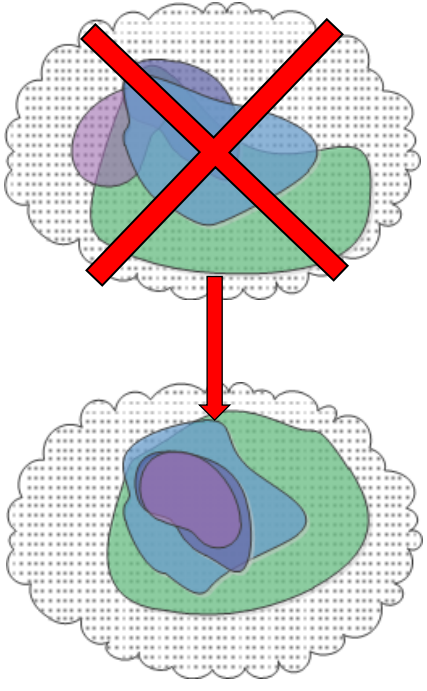
Conflicted De-Conflicted Coordinated Collaborative Edge

H2: Results – Agility Score by C2 Maturity Level



H2: Results – Agility Score by Maturity Level and C2 Approach





Experimental results suggest more an imbricated model than a complementary one

H2: Results of the Statistical Test

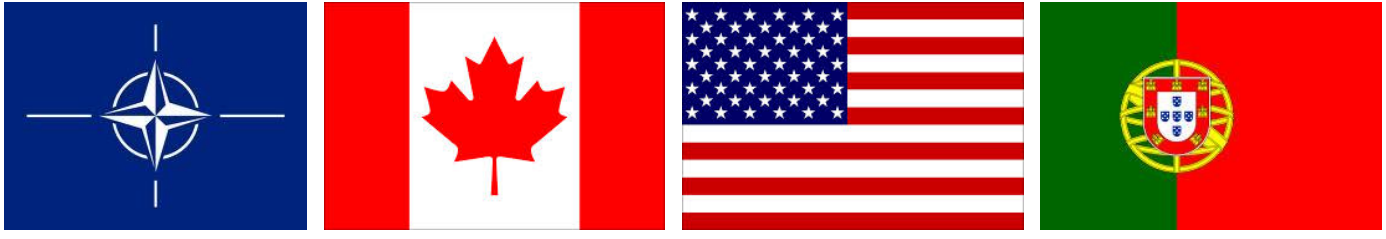
- The difference of Endeavour Space coverage (M = 0.003) by a C2 Maturity Level and the most network-enabled C2 Approach it includes is statistically significant $t(17) = 2.44$, p = 0.01
- However, a value of 0.3% represents a small benefit
- Such a small gain can be explained by a few factors
  - Endeavor Spaces were populated by quantitatively different circumstances, thereby exaggerating some effects → More diversity would have been required
  - Missions success was measured on a binary scale for some experiments, making it impossible to perform refined comparisons
  - No experiment implements the higher ability of higher levels of C2 Maturity to pre-emptive/early transition between C2 Approaches

Summary

- The results largely confirm the first hypothesis, namely that more network-enabled C2 Approaches are more agile
- Ability to successfully cope with the Endeavor Space increases quadratically as a collective adopts a more network-enabled C2 Approach (probably due to increased level of connectivity)
- There is some value added by being able to adopt a variety of C2 approaches provided by a level of maturity as opposed to adopting the most network enabled for all situations
- The advantages of C2 Maneuver need to be experimented with and analysed further
- Three other papers (#034, #048, #066) on this experiment are presented in this conference

SAS 085

C2 AGILITY AND REQUISITE MATURITY



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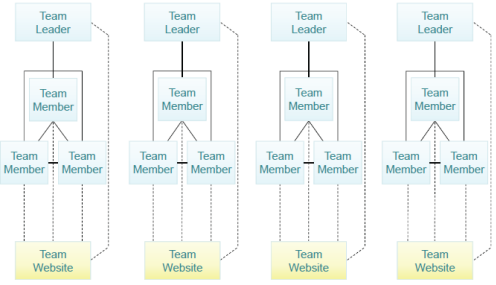
IDA

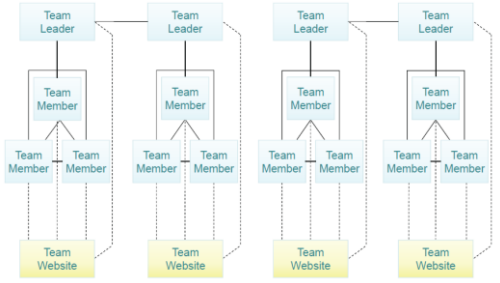
Rigorous Analyses ▪ Unquestioned Objectivity

Scenario - ELICIT

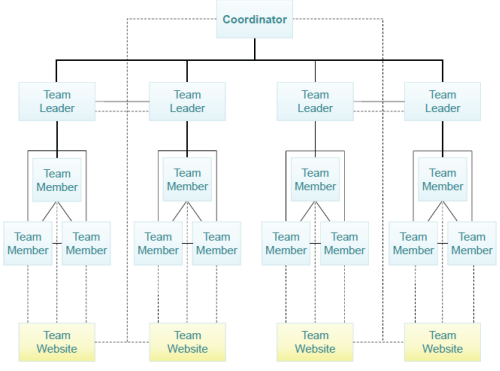
Conflicted



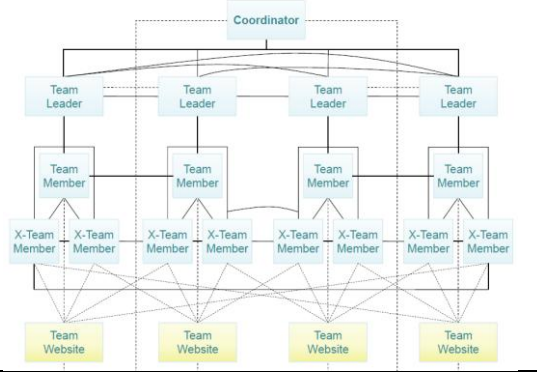
De-Conflicted



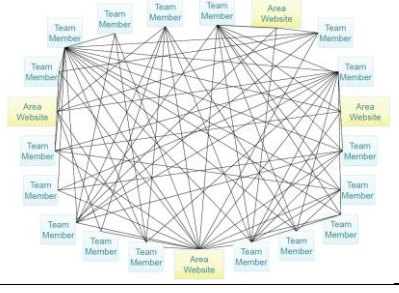
Coordinated



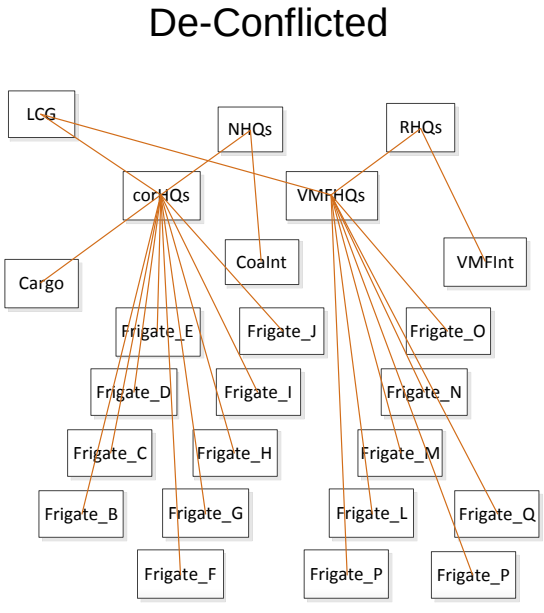
Collaborative

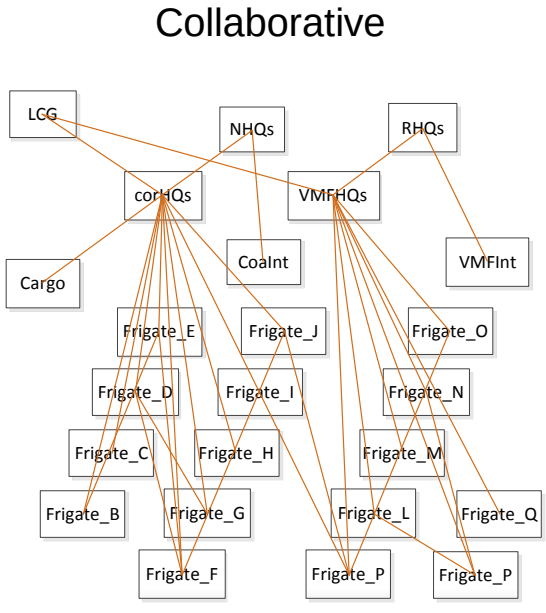


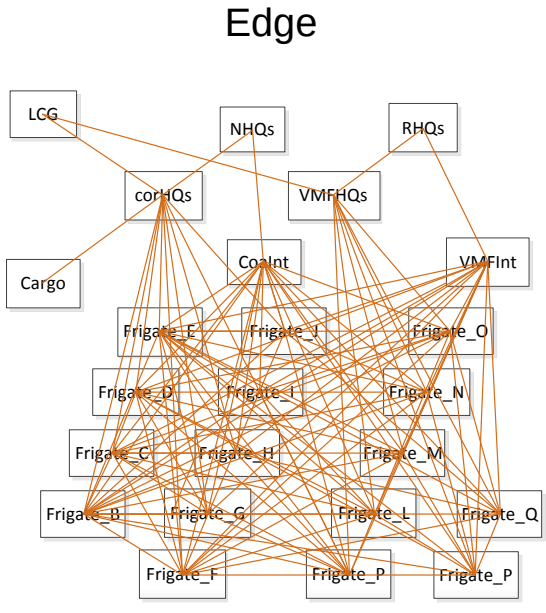
Edge



Scenario - PANOPEA







Scenario - IMAGE

C2 Approach	ADR	PoI	DoI	Planning process
Conflicted	Each organization decides of its unit locations and activities	Between units of the same organization	Between units of the same organization	Move units(s) to most problematic province(s) and then select the activity for each unmoved unit that impacts the variable with the lowest value
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	Like in *conflicted* but conflicting activities are not allowed
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)	Like in *conflicted* but all possible interactions between activities with collocated units are considered
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.)	All combinations of unit locations and activities are considered; those with the higher impact are retained.