

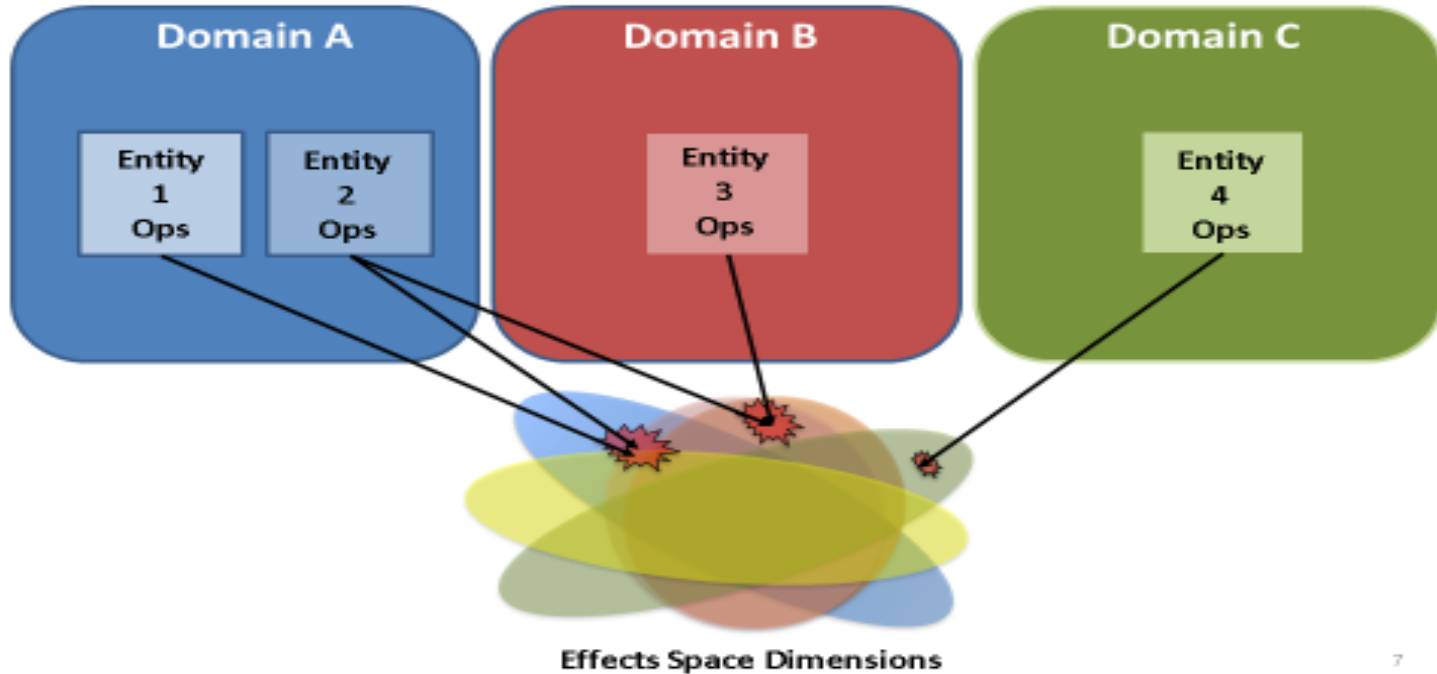


Agile Multi-Domain C2

NATO SAS-143

presented to
23rd ICCRTS
November 2018

Example of a Multi-Domain Enterprise



Terminology

- In recognition that some MDO that NATO and its member nations undertake will involve a disparate set of entities, some of whom do not use the term “C2” to refer to their management or governance arrangements and who are ‘sovereign actors’
- SAS-143 has adopted the term harmonization to refer to both their internal arrangements and their arrangements with others.
- Thus MDC2 will be replaced by MDC2-H

MDC2/H

Multi-Domain C2/Harmonization seeks to avoid conflicts and enable synergies within, between, and among entities conducting operations in multiple domains, and the effects that these operations create

MDC2/H involves both

- Approaches that are adopted by each of the entities in each of their operating domains
- The arrangements that govern behaviors between and among the set of entities participating in a MDO

Foundational Hypothesis

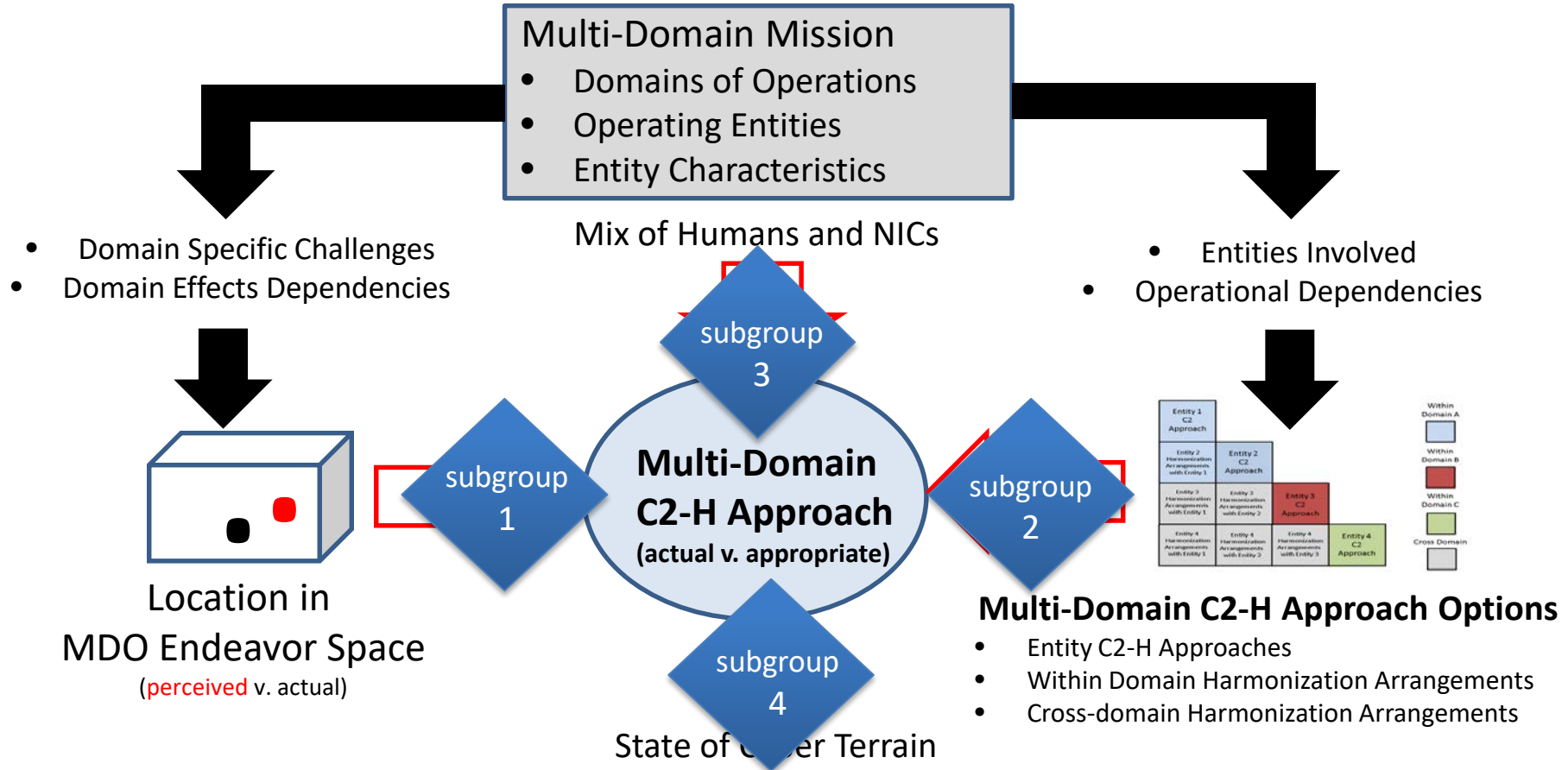
The most appropriate entity-domain approaches to C2, Governance, or Management cannot be determined without considering the nature of the MDO and the participating partners
(requires a holistic design)

SAS-143 Approach

SAS-143 will explore a set of hypotheses by means of

- Experiments
- Case Studies
- Existing research findings

MDO/MDC2-H Conceptual Model

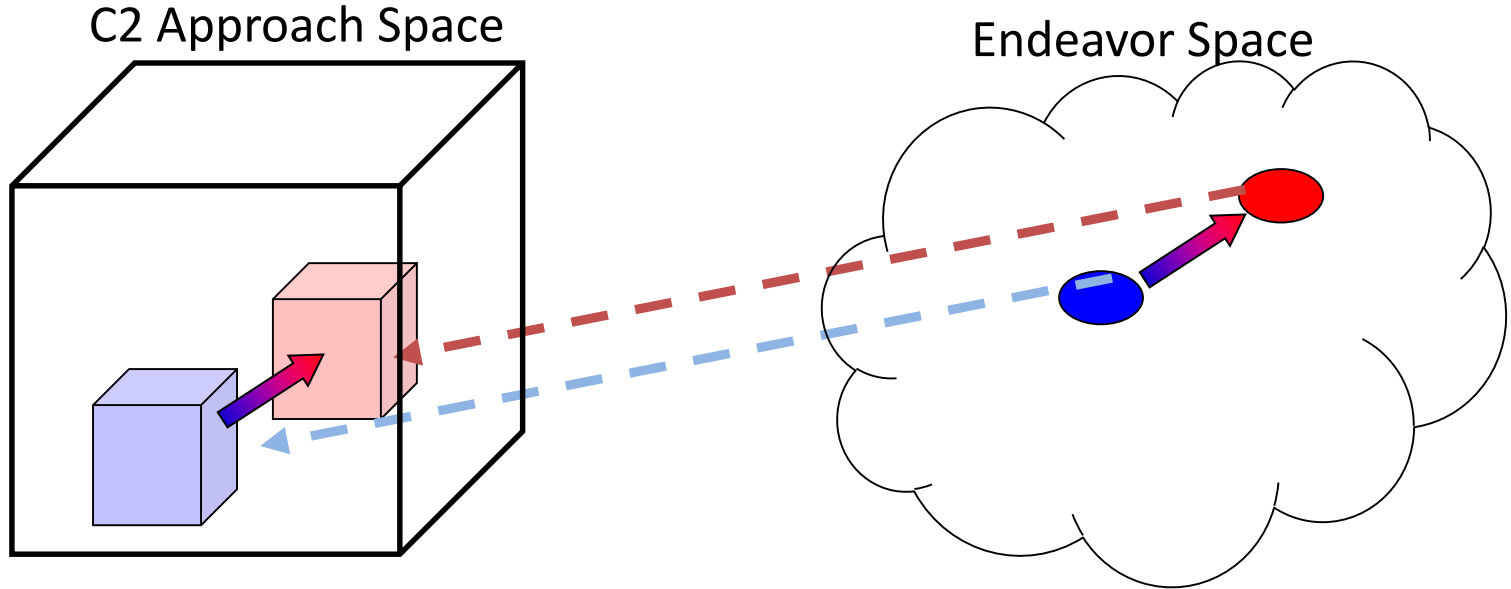


SAS-143 Subgroups

- Subgroup 1 – Endeavor Space and Case Studies
- Subgroup 2 - MDC2/H Approach Space and Experiments
- Subgroup 3 – Non-Human Intelligent Collaborators
- Subgroup 4 – Cyberspace Operations and Terrain

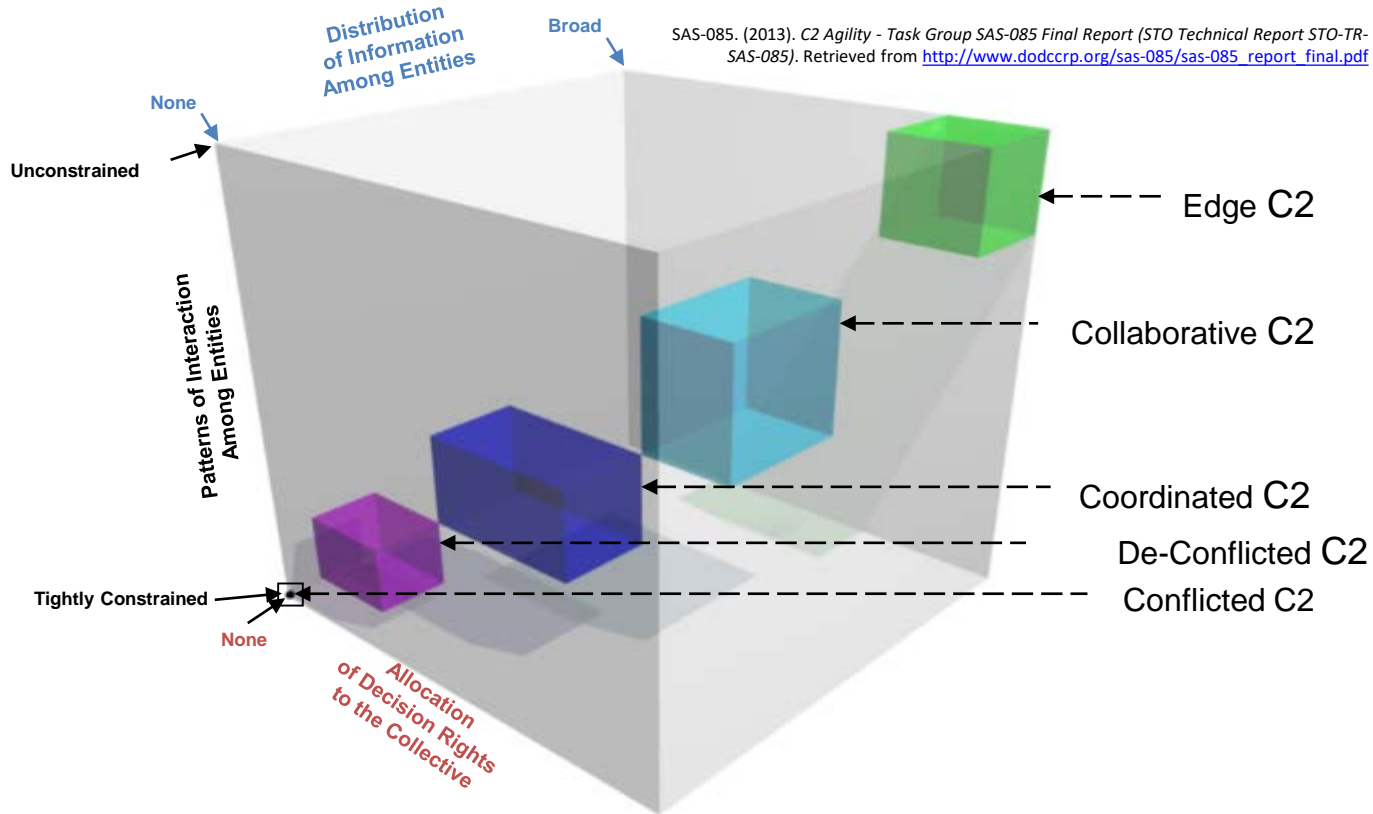
Subgroup 1 – Endeavor Space and Case Studies

C2 Agility

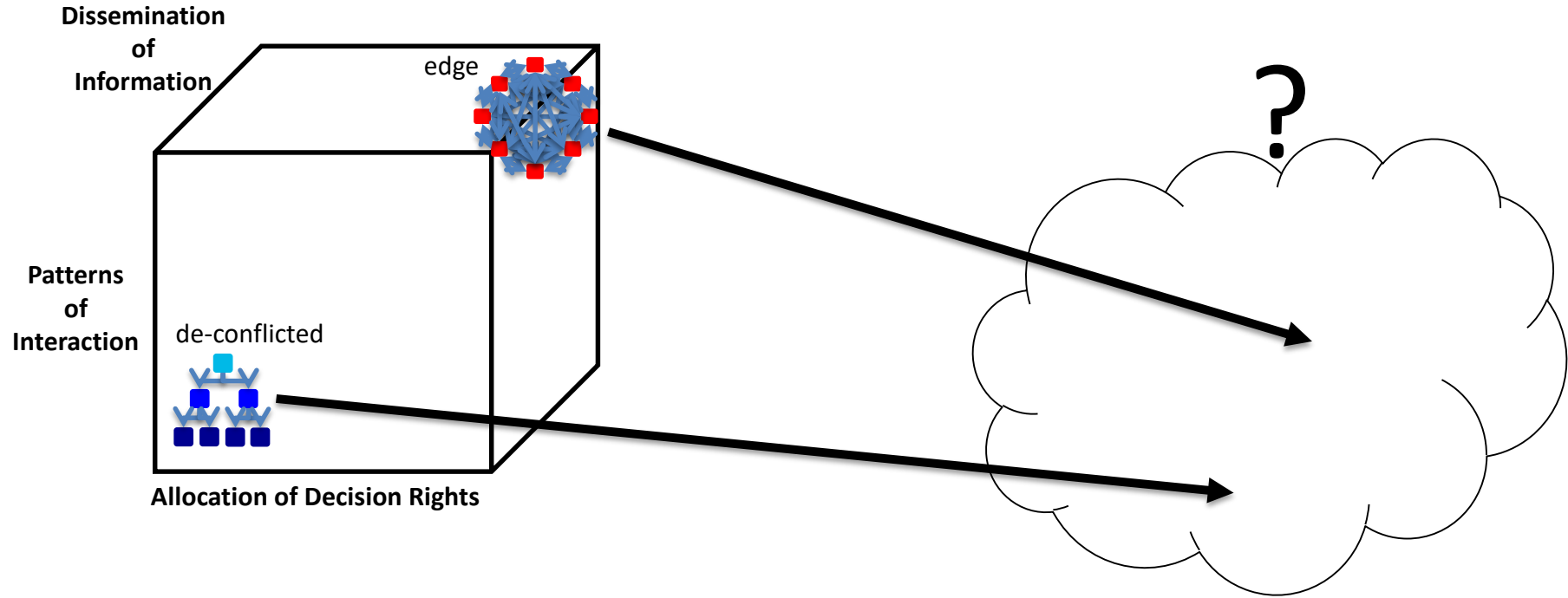


- SAS-085 postulated that there is an “appropriate” C2 Approach for each region of the Endeavour Space
- Agile C2 requires an understanding of which C2 approach is most appropriate for a given location in the Endeavour Space

The C2 Approach Space



The Endeavour Space is just a fluffy cloud



The C2 Approach Space has a set of dimensions that facilitates observation and analysis

The Endeavour Space does not! (yet)

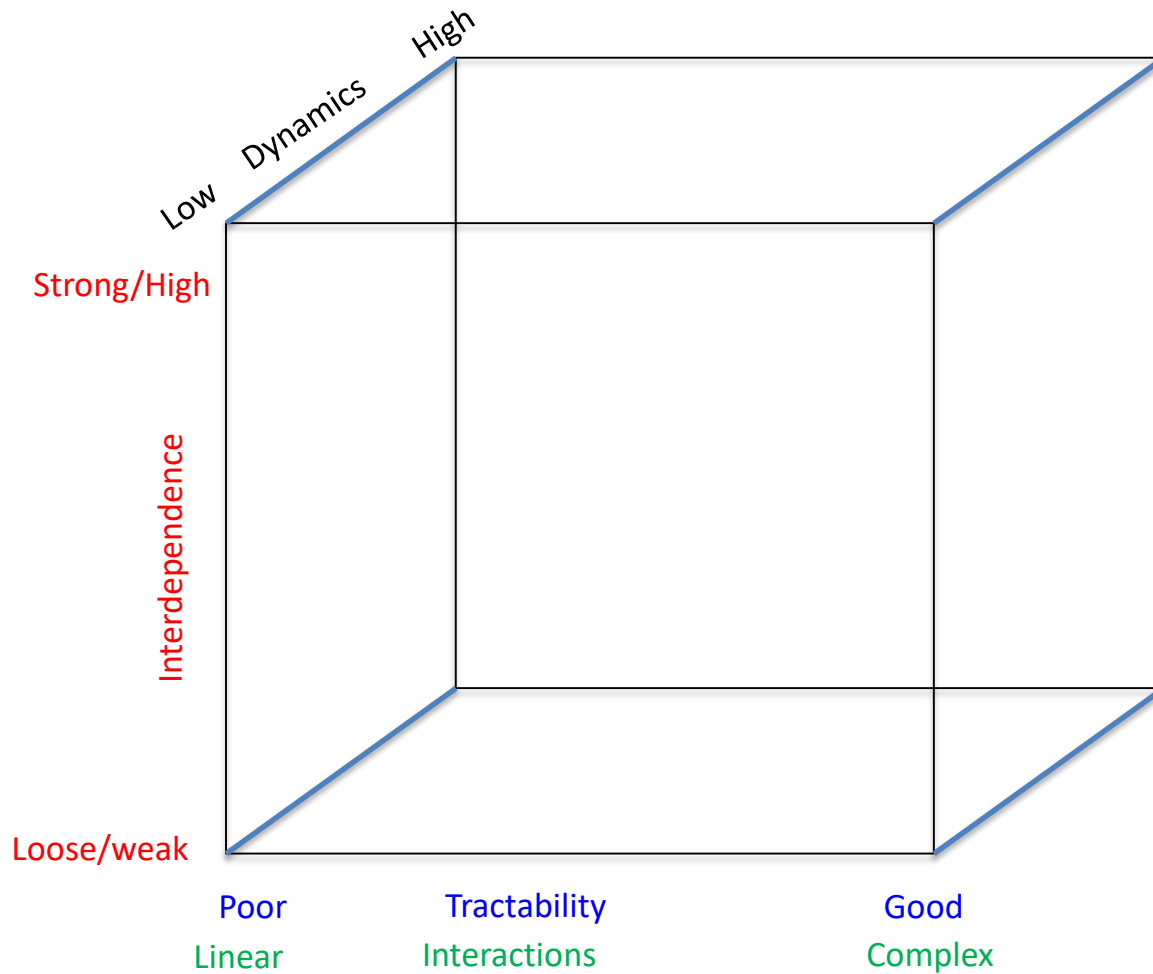
SAS-143 Endeavour Space Challenge

- The dimensions of the C2 Approach Space have been measured and employed in case studies (qualitatively) and in experiments (quantitatively)
- In these case studies and experiments the Endeavour Space has been represented by unique sets of variables that varied from study to study (e.g. degraded network, cognitive complexity, time pressure)
- Thus, the Endeavour Space needs to be systematically and uniformly characterized for continued progress
- SAS-143 Endeavour Space Challenge: What are the dimensions of the Endeavour Space, that is, what makes one endeavor different from another from a C2 perspective?

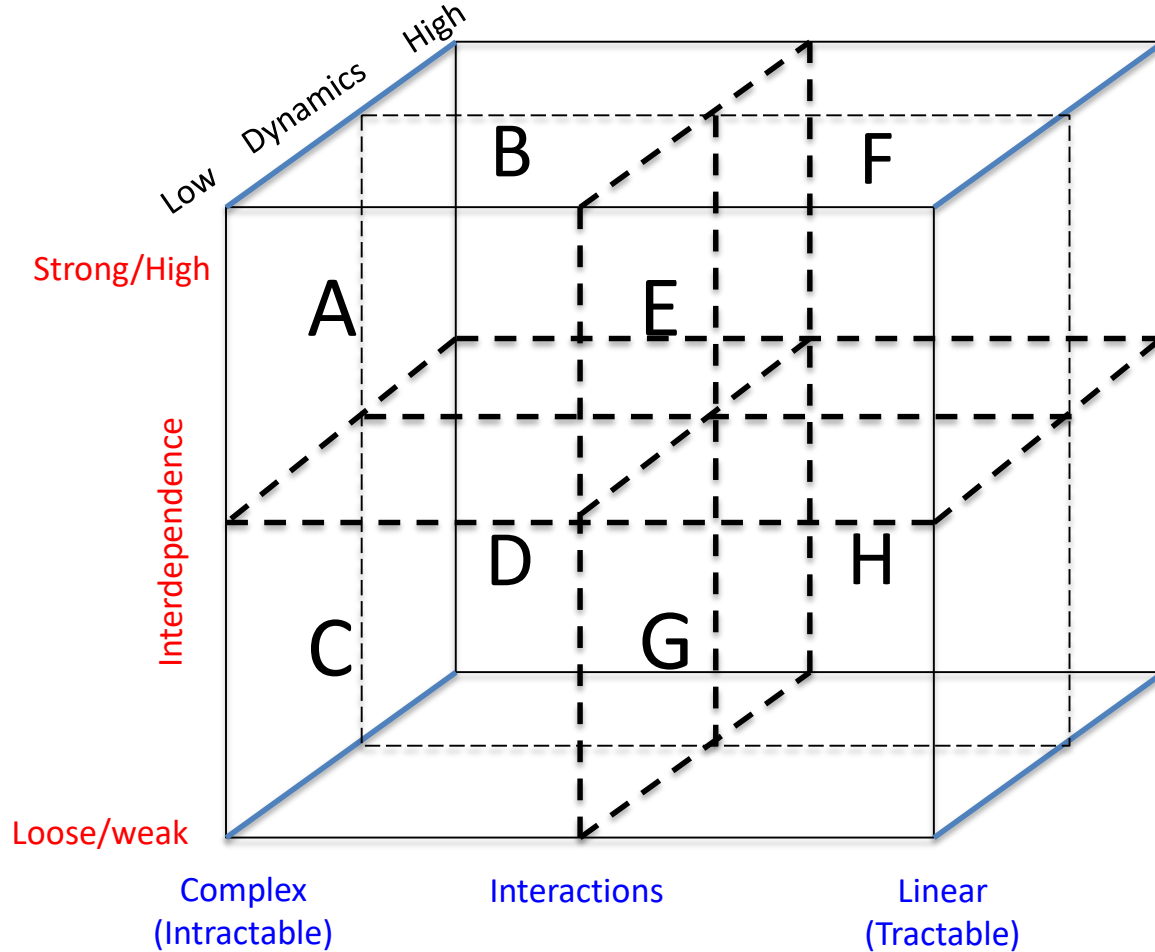
Endeavour Space Dimensions

SAS-143 will be exploring the utility of the following dimensions to define the Endeavour Space

- » Dynamics
- » Interdependence
- » Tractability



Endeavour Space Regions



Endeavour Space Regions

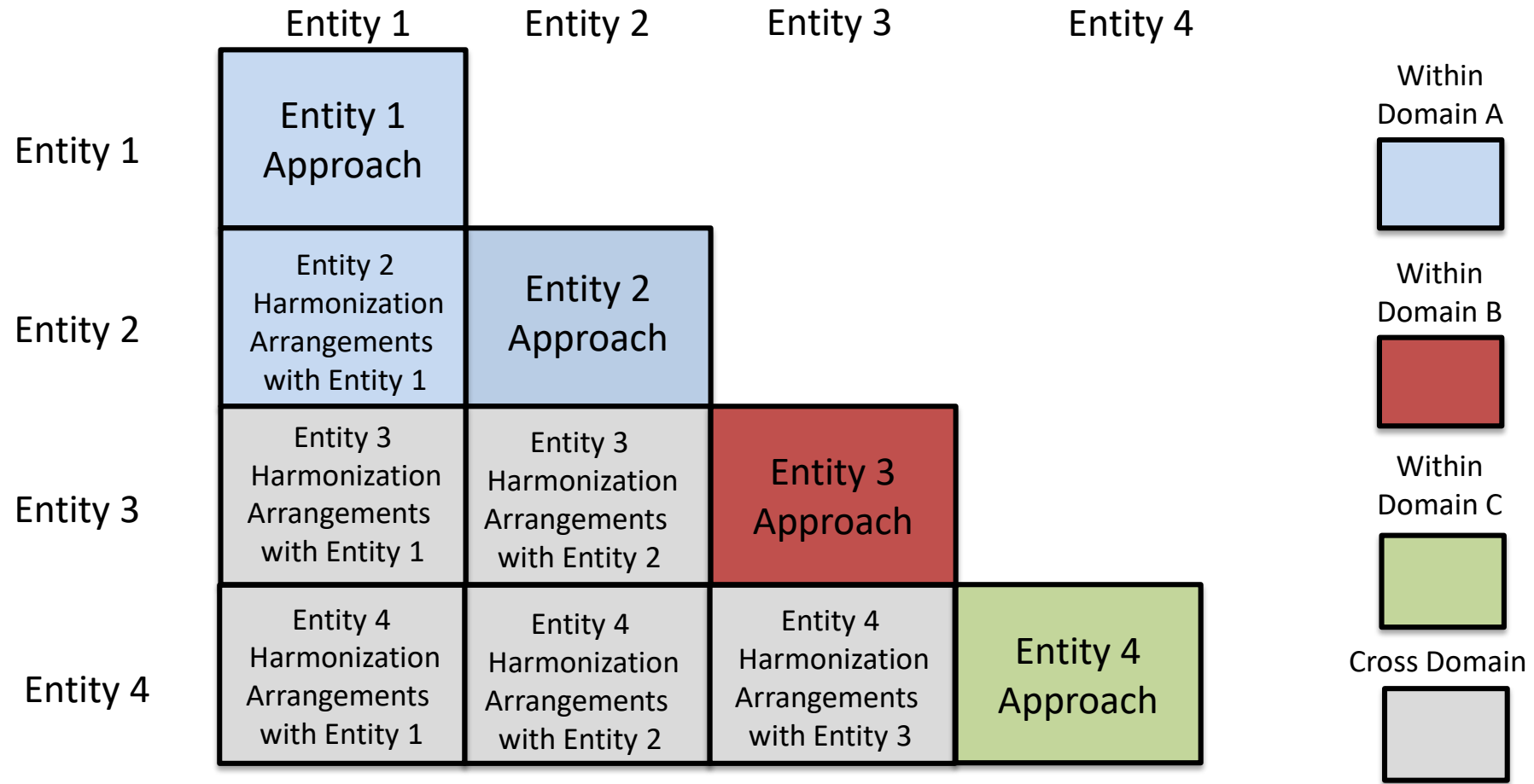
- A. Intractable, tightly coupled, non-dynamic
- B. Intractable, tightly coupled, high-dynamic
- C. Intractable, loosely coupled, non-dynamic
- D. Intractable, loosely coupled, high-dynamic
- E. Tractable, tightly coupled, non-dynamic
- F. Tractable, tightly coupled, high-dynamic
- G. Tractable, loosely coupled, non-dynamic
- H. Tractable, loosely coupled, high-dynamic

Subgroup 2 - MDC2/H Approach Space and Experiments

- MDC2/H Approach Space
- Hypotheses
- Experiments

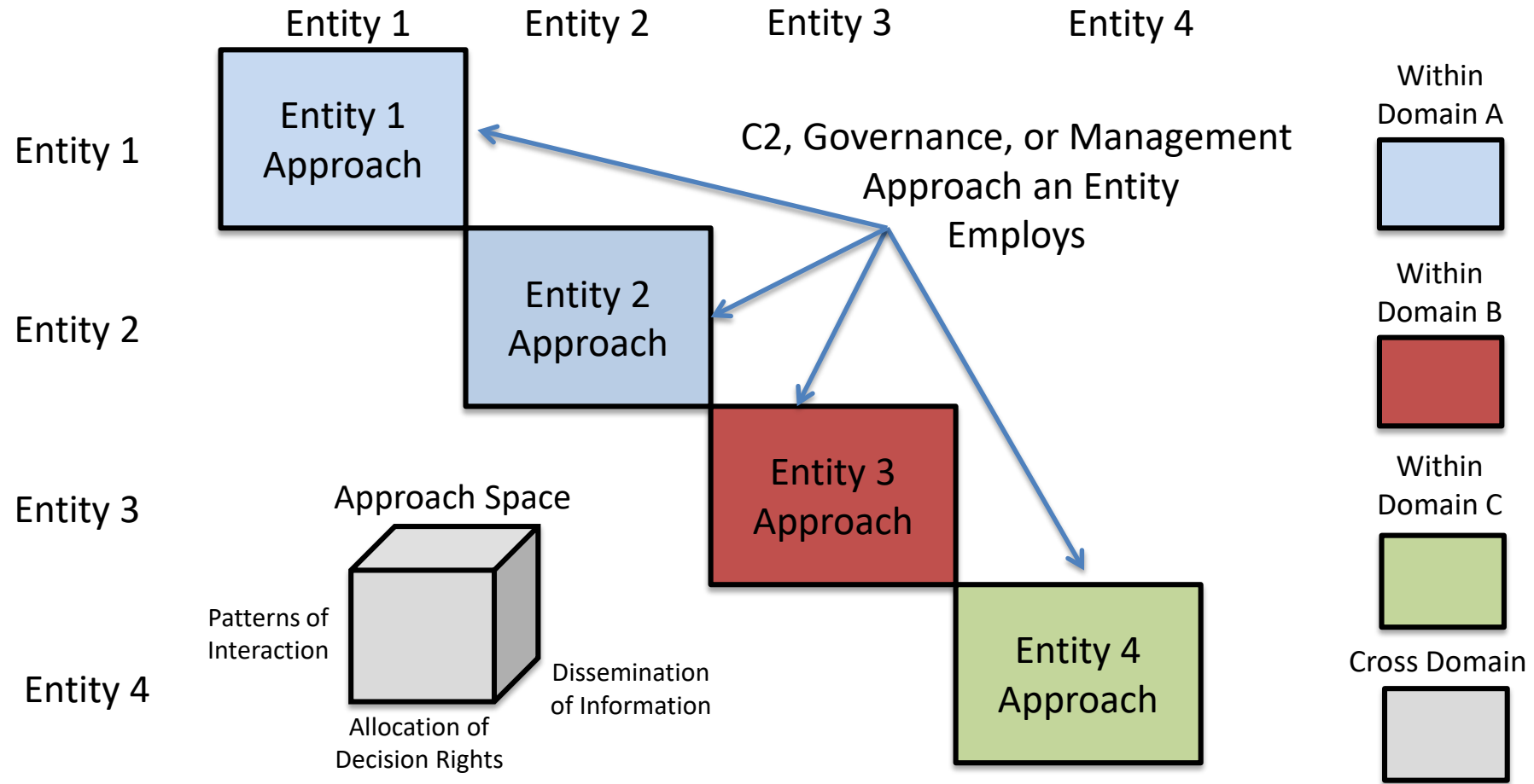
MDC2/H Approach with 4 Entities Operating in 3 Domains

With Symmetrical Cross Domain Arrangements



MDC2/H Approach with 4 Entities Operating in 3 Domains

With Symmetrical Cross Domain Arrangements



MDC2/H Approach with 4 Entities Operating in 3 Domains

With Symmetrical Cross Domain Arrangements

Entity 1

Entity 2

Entity 3

Entity 4

Entity 1

Entity 2

Entity 3

Entity 4

	Entity 2 Harmonization Arrangements with Entity 1		
	Entity 3 Harmonization Arrangements with Entity 1	Entity 3 Harmonization Arrangements with Entity 2	
	Entity 4 Harmonization Arrangements with Entity 1	Entity 4 Harmonization Arrangements with Entity 2	Entity 4 Harmonization Arrangements with Entity 3

- Use C2 Approach Space Dimensions
 - modify-add dimensions
 - New conceptual approach

?

Within
Domain A



Within
Domain B



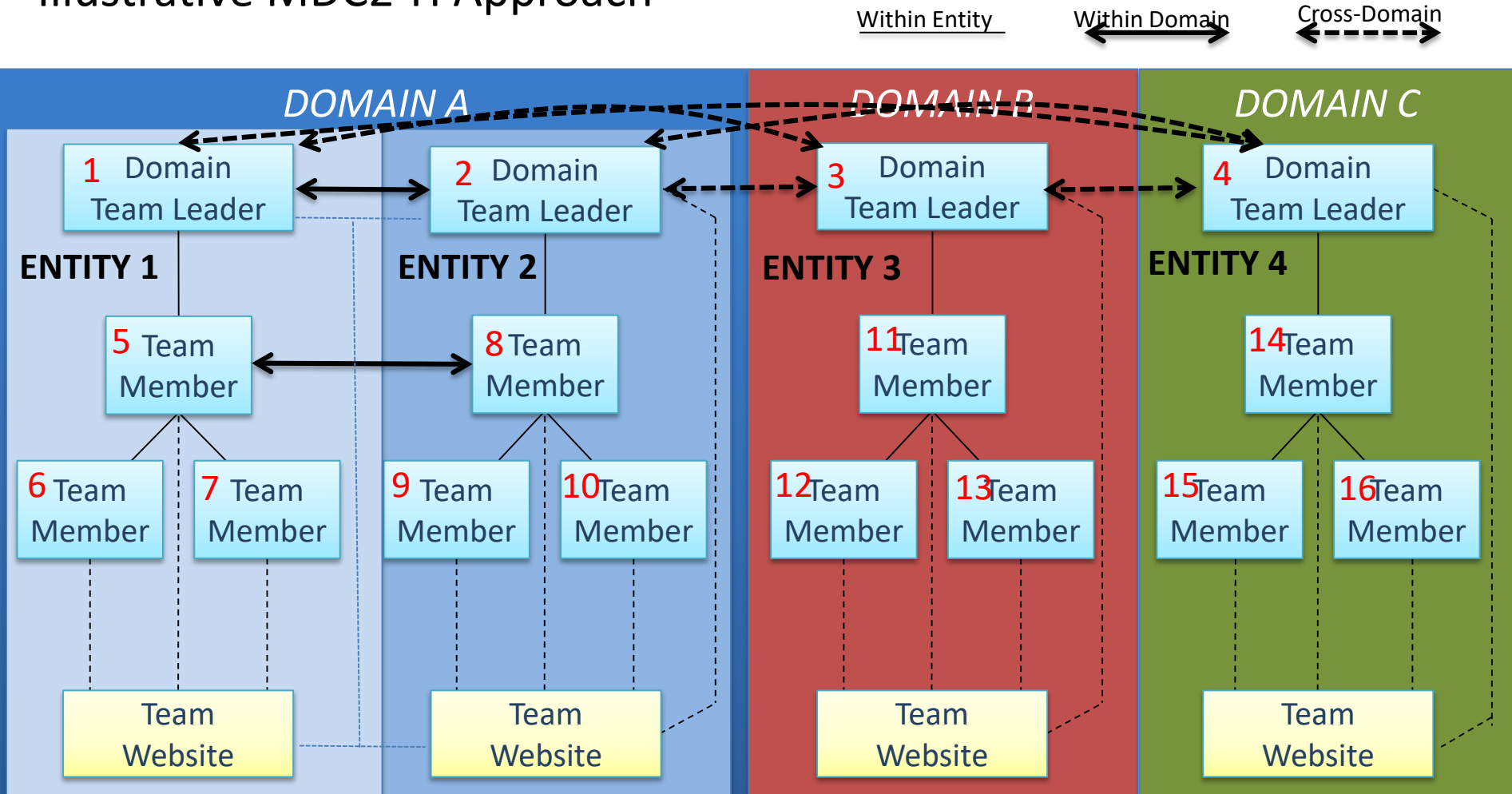
Within
Domain C



Cross Domain



Illustrative MDC2-H Approach



Hypotheses: MDC2 Harmonization

partial and preliminary

[A1] In operations that involve two or more domains (MDO), a Harmonization Approach is required to achieve an appropriate level effectiveness, efficiency and/or agility given the MDO

[A1.1] The level of shared awareness necessary to achieve harmonization is a function of the interdependencies between and among entity operations and/or the effects created.

[A2] Harmonization can be achieved by emergent self-synchronization that results from a large number of non-human entities, individually and collectively contributing to shared awareness and sensemaking.

Hypotheses: Appropriateness of Domain Approaches in MDO

partial and preliminary

[B1] Participating in an MDO sometimes requires entities to adapt their domain C2,G,M Approaches in order to make harmonization feasible

[B1.1] An entity's domain C2,G,M Approach adaptations required for MDO will move domain Approaches away from the 'origin' of C2 Approach Space by increasing the delegation of decision rights, increasing interactions, and/or more widespread access to information) to improve shared awareness and harmonization. *[this is expected to be true for entities that have adopted less-networked-enabled domain approaches]*

Experiments

- ELICIT is being employed initially, while other experimentation environments are being identified.
- SAS-085 ELICIT results will serve as a baseline to compare with MDO experiments
- ELICIT organizational files have been created for a 4-Entity MDO with a variety of 'harmonization' interactions and degrees of information sharing
- ELICIT 'factoid sets' have been modified for a set of MDO challenges Initial runs show that mission dependencies
- Initial runs mirror SAS-085 findings
- We are ready to begin exploring SAS-143 hypotheses

Subgroup 3 – Non-Human Intelligent Collaborators

Why?

- The use of unmanned, autonomous, intelligent systems in military operations including C2 is expected to grow extensively.
- This will have an impact on the people working with these ‘non human intelligent teammates’.



Objective

- Gain insight in the implications for C2 caused by the deployment of non-human entities (NIC or AS) operating by themselves or in mixed teams. (e.g. allocation of decision rights, span of control, human decision making, ... ect.)

Definitions

- A **Socio-Technical Organization** is an organization or collections of organizations where significant decision rights and autonomy are granted to non-human intelligent collaborators (NIC) or Autonomous Systems (AS).
- A **NIC** is an artificial entity which is able to autonomously engage with its environment in direct interaction, involvement and/or interdependency with humans and other artificial entities in order to meet a certain objective. Besides deciding and acting on an individual basis, both the human and the artificial entity complement each other's decision making process and actions. In order to do so, they must be able to understand complex ideas (relative to the activity), to adapt effectively to the environment and to combine task related- with social and team related skills that enable effective and efficient collaboration.

Research questions

- How will collaborating with a NIC influence human DM?
- How will collaborating with a NIC influence human risk taking?
- How will collaborating with a NIC influence the C2 approach?
- In what way will collaborating with a NIC affect C2 agility?
- How will collaborating with a NIC influence the C2 approach in different domains (e.g. cyber operations)?
 - Can NICs support to overcome time-response difference between the domains?
- How will collaborating with a NIC influence (the speed of) distribution of information within the system?

Research questions

- What are requirements for acceptance of NICs in military units (as team members)?
 - What allocation of decision rights would be preferable depending upon the level of acceptance and trust of the NIC?
 - How will the properties/ capabilities of a NIC relate to C2 arrangements?
- What are the challenges associated with commanding NICs? Depending on the configuration of the NIC.
 - Will humans be able to intervene or control NIC actions in a timely manner?
 - Will commanders be able to understand what the NICs are doing and their intentions?

Hypotheses [Set C] NIC & AS

partial and preliminary

- [C1] The locations of C2 Approaches in the C2 Approach Space are not affected by the extent to which decision rights are allocated to non-human entities.
- [C2] C2 Approaches that involve the delegation of decision rights to non-human entities will be more agile. This must be tested for each C2 approach.
- [C3] C2 Approaches that involve the delegation of decision rights to non-human entities will be more efficient when the operation is going as planned but less efficient when the situation changes
- [C4] Will delegation of decision rights be accepted by the human counterpart in a human-automation constellation?

Subgroup 4 – Cyberspace Operations and Terrain

Cyberspace Subgroup Focus

- C2 of Cyberspace Operations
 - Since there is no 'one size fits all' approach to C2 for all missions and circumstances, it follows that we need to determine what would be an appropriate approach to C2 for various types of Cyberspace Operations?
- Implications of operating in contested cyber environments
 - The likelihood of operating in a cyber-contested environment is very high increasing the need for C2 Agility and the need to understand the impacts of degraded CSM upon C2 Approaches.

Hypotheses [Set D] Cyberspace Operations and Cyber Contested Environments

partial and preliminary

[D1] Cyberspace Operations with different missions and circumstances are located in different regions of the Endeavor Space

[D2] Defensive Cyber Operations (DCOs) undertaken in highly contested cyber environments requires a delegation of decision rights to non-human entities

[D3] DCOs have the potential to affect the appropriateness of C2 approaches for operations in other domains as well as other Cyberspace Operations by adversely impacting accesses to information and/or the flow of information

[D4] The mapping between the CSO Endeavor Space and C2 Approach Space will depend upon the degree to which decision rights are delegated to non-humans.

[D5] In cases when an Endeavor involves more than one Cyberspace operation, the C2 Approaches associated with each of these need to be harmonized to avoid conflicts between and among them and the effects they each create.

Cyberspace Research Questions

[R1] What is the Endeavor Space for Cyberspace Operations ?

[R2] To what extent does the C2 of DCO, OCO, and CSM need to be harmonized?

[R3] How does operating in a cyber contested environment

- Change one's approach to C2 of Cyberspace Operations?
- Change one's approach to C2 of operations in other domains?
- Impact agility?

[R4] Will Leaders/Commanders be able to understand the cyber relationships (interdependencies and vulnerabilities) that exist between and among the diverse set of organizations involved in an MDO (e.g. military, civilian government, industry, ...)?

[R5] How could commanders utilize non-human entities to develop cyber situation awareness and execute cyberspace operations?

[R6] Will the DOTMLPF associated with different C2 Approaches for Cyberspace Operations be affected by different outcomes of each?

Subgroup Work Plan: Next Steps

working as appropriate with other subgroups

- Continue literature review – a number of publications and papers have already been identified to help inform results
- Identify key variables, differences, interdependencies between and among
 - Cyberspace v. Physical, Social Domains
 - DCO, OCO, and Cyber support to missions (CSM)
- Investigate if there are simulations (e.g. ELICIT or UK “Serious Gaming”) and exercises that could be useful to explore Cyberspace-related hypotheses
- Identify real world Cyberspace Operations that we can study (UK-Cranfield University case studies)

SAS-143 Call for Participation

