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The Influence of Harmonization Levels on Multi-Domain Operations Effectiveness:the Moderating Roles of Organizational Environment and Command and Control Variety

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The influence of harmonization levels on multi-domain operations effectiveness: The moderating roles of organizational environment and command and control variety

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Abstract

This paper presents a research model regarding inter-entity collaboration. Today's mission environments often require collaboration between and among entities. Such collaboration we conceptualize as harmonization: transforming a set of entities into an effective enterprise by using harmonization arrangements to achieve collaboration. Harmonization varies as to the closeness of collaboration and we call this variation harmonization levels. Recent command and control (C2) theorizing in the NATO research group SAS-143 have suggested that selecting the appropriate harmonization level, closeness of collaboration, may positively influence multi-domain operation (MDO) effectiveness. In this paper, we discuss whether specific aspects of the organizational environment, uncertainty and ambiguity, and C2 variety moderates a positive relationship between harmonization level and MDO effectiveness. We argue that higher harmonization levels will be more positive for MDO effectiveness when environmental uncertainty and ambiguity is high. C2 variety we define as having three dimensions: the C2 approach of an entity, its harmonization options available, and its ability to make use of its C2 approach to integrate with other entities. We suggest that higher C2 variety together with environmental uncertainty and ambiguity will further strengthen the positive relationship between harmonization level and MDO effectiveness. We draw on a case study to develop the notion of C2 variety; we then develop hypotheses about the interactions among harmonization level, organizational environment and C2 variety. Finally, we discuss theoretical implications, suggestions for future research, and implications for practice.

Keywords: Multi-domain operations effectiveness, Harmonization levels, Organizational environment, Command and control variety.

1 Introduction

Entities, understood as organizations and/or teams[1], sometimes need to collaborate with other entities in multinational military operations and civil-military relief operations and multi-domain operations (MDO). [2] One particular challenge in this respect is collaboration between entities that do not have the same approaches to command and control or have similar governance structures. [3] The SAS-143 research group (SAS-143) have conceptualized the collaboration between entities as harmonization (Alberts et al., forthcoming) drawing on prior research such as Brehmer (2010a and 2010b).[4] Harmonization is the task of transforming a set of entities into an effective enterprise in which the entities can work together, and the harmonization arrangements (i.e. ways of communicating, sharing information etc.) participating entities use to achieve collaboration. Collaboration we define as helping other entities in accomplishing work, encompassing both cooperation, integrating interests, and coordination, integrating activities (Kretschmer & Puranam, 2008; Kretschmer & Vanneste, 2016). Alberts et al. (forthcoming) have suggested that harmonization arrangements vary as to the level of closeness and complexity of working relationships, i.e. collaboration. This variation of closeness is referred to as harmonization levels (also called harmonization options) with higher levels characterized by more closeness of collaboration than lower levels (Alberts et al., forthcoming). A crucial question is whether higher harmonization levels positively affect MDO effectiveness.

Prior research on interorganizational collaboration (IOC) suggests that IOC is most successful, in reaching goals the entities hold in common, when the organizations undergo complex changes characterized by closer collaboration between the organizations (Majchrzak, Jarvenpaa & Bagherzadeh, 2014). The research on IOC suggest in particular three factors that relate positively to IOC success, changes of an IOC in the direction of more cooperative

[1] We use the terms entity and organization interchangeably in this paper.

[2] MDO are operations comprising entities from physical, virtual and social domains.

[3] While the term C2 does not necessarily encompass management of non-military organizations, in this article we focus on military-to-military collaboration with military entities from different domains, i.e. a multi-domain operation.

[4] This paper draws heavily upon the ongoing work and the interim products of the North Atlantic Treaty Organization (NATO) Scientific Technology Office (STO) Research Group SAS-143 Agile multi-domain C2 of socio-technical organizations in complex endeavors. The final report of SAS-143 is expected to be completed in the Spring of 2021.

interaction style, organizations share information between them openly, and more relationship-based contracts, which are characterized by close trusted and interdependent relationships between organizations (Majchrzak et al., 2014; Oliveira & Lumineau, 2019).

However, we argue that the relation between harmonization level, i.e. closeness of collaboration between entities, and MDO effectiveness may depend on factors that are both external and internal to the entities. Firstly, we argue that some core characteristics of the organizational environment, both its uncertainty and ambiguity (Schneider et al., 2017; Dess and Beard, 1984; Daft and Lengel, 1984) affect the relationship between harmonization level and MDO effectiveness. Our concept of organizational environment encompasses volatility, uncertainty, complexity and ambiguity of the environment (VUCA). We suggest that a higher harmonization level will influence MDO effectiveness more positively when the environment is highly uncertain and ambiguous as compared to a less uncertain and ambiguous environment. In highly uncertain and ambiguous environments, we argue that there is more need for an organization to collaborate closely with other entities because they have a higher need to draw on other organizations to solve and understand problems (Schneider et al., 2017; Weidl & Serle, 2018).

In order to be able to exploit a high harmonization level, we also argue that the entities internally will need to prepare for collaboration. In this respect, we build on the notion of C2 variety in Alberts et al. (forthcoming). C2 variety is defined as, 1) the C2 approach of an entity (i.e. allocation of decision rights, patterns of interactions and distribution of information) and 2) the harmonization levels available for the entity. We add to this a third dimension: 3) the ability to make use of its C2 approach to integrate with other entities. We argue that if there is a higher C2 variety, the organization would more easily be able to work at a higher harmonization level and utilize it to contribute better to the task resolution in highly uncertain and ambiguous environments. We argue that when entities have higher C2 variety they can give decision rights to their members so that they can collaborate with other entities (allocate decision rights), they can provide resources to other teams and they can engage in collective routines (patterns of interaction) with the other entities, and they can share information with other entities (distribution of information). While entities that have lower C2 variety may be able to

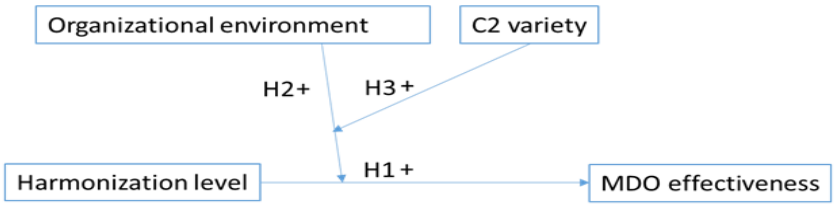
collaborate with other entities, such entities have smaller repertoire for engaging in such collaboration. This could restrict with whom they can collaborate.

We draw on theories of cybernetics and organization design to substantiate our line of reasoning. The theory of cybernetics suggests that entities will need requisite variety, i.e. represent the complexity of the system to which it belongs, in order to function well within that system. (Ashby, 1956). Similarly, in the contingency perspective, the key assumption is that the external environment of an organization and the internal structure and processes of an organization should be aligned to enable high performance (Lawrence & Lorch, 1967; Van de Ven, Ganco & Hinings, 2013). This suggest that both the environment and internal C2 variety could influence the utility of harmonization levels.

On this background, the purpose of this article is to explore the research question: To what extent do harmonization level, organizational environment and C2 variety interactively influence MDO effectiveness? We elucidate the question through developing a research model and hypothesis. As one of the backgrounds for developing our research model and hypotheses we firstly, in part 2, move one step back and explore the concept of C2 variety. We sought to increase our understanding of that concept building on a case of multi-entity collaboration in a military context, specifically a joint intelligence surveillance and reconnaissance (JISR) exercise focusing on federated processing exploitation and dissemination (PED) (Haugen, Ellingsen-Rustad & Stensrud, 2019). In part 3, we develop insights on the relation among harmonization levels, organizational environment and C2 variety and build hypotheses on their effect on MDO effectiveness, taking into account, amongst other things, the development of the C2 variety concept. We present in figure 1 below, schematically, the relations and hypotheses in our research model. Finally, in part 4, we discuss some theoretical implications, prospects for future research, and potential practical implications.

Figure 1

Theoretical model of the consequence of Harmonization level, Organizational Environment, and C2 variety on MDO effectiveness



The hypotheses are indicated as H1, H2 and H3

2 An empirical illustration and conceptual development of C2 variety

What do we mean by C2 variety? In this part, C2 variety is illustrated and developed by the findings from the NATO exercise Unified Vision 2018 (UV18) in which multiple entities were to collaborate. This provided us with access to a multi-domain enterprise that could benefit from close inter-entity collaboration. We first briefly describe the exercise, specify what aspects of C2 variety we argue need more elucidation, presents the method for this particular examination of C2 variety, and then presents some findings on the concept of C2 variety.

The exercise was a multinational JISR exercise were multiple entities collaborated to produce JISR-products (Haugen et al., 2019). In multinational Defense operations, either EU or NATO driven, the exchange of surveillance and reconnaissance data and information is an essential aspect to be able to act promptly. In the NATO context, the JISR process supports the execution of surveillance and reconnaissance tasks. Specifically, the case study presents results from a NATO Exercise aiming to explore support mechanisms and guidelines for automation of systems supporting a federated work process concerning the processing exploitation and dissemination of information (PED). In this exercise a more dynamic and decentralized way of working together across nations, as compared to prior exercises, was tried out.

Each nation have one or more PED cells. PED is the transformation of raw collected data into usable information distributed for further analysis and/or used as combat information by commanders and staff. To specify more the PED process is a collection of functions that fit into one of the following three categories: 1) Processing: The automated or human cognitive-based conversion of collected data into usable information. Collected data could originate from human and technical sensors, such as advanced fighter aircraft sensors, unmanned aerial vehicles etc.. Such differences could exemplify differences among the emphasis of the PED cells on the physical domain (e.g imagery) or the virtual (e.g. analysis of cyber threats). 2) Exploitation: The refinement of raw data to provide information by trained personnel or automation (machine systems). 3) Dissemination: The distribution or reporting of relevant information in a format suitable for commanders, staff, analysts, and other consumers, as well as done machine-to-machine (Haferkorn, D. et al., 2019). While these components of the task are traditionally done within PED cells, there are now changes to this way of working.

Federated PED is a concept of collaborating PED nodes e.g. Collection Management elements can plan, task or request component or higher, lower and adjacent level PED nodes and resources (Thiele, 2014). This means that the tasks formerly given to distinct national PED cells could now be split among different nations cells. The concept of a federated PED builds upon existing and emerging capabilities where the PED task can be quickly assigned to the most qualified entity to process and analyze the data anywhere, regardless of the sensor, and then pass it on to support any shooter and/or decision maker at the right place and time. One nation, could, for example do the processing for a particular type of information and another could exploit and disseminate it. We think this aspect of the exercise exemplify in a good way a situation where different entities are thought to harmonize, and where there may be differences among the entities as to their C2 variety. There are overarching procedures for JISR at the multinational level in NATO but there is no detailed procedure for federated PED. Therefore, the case illustrates a situation where different entities may have different internal approaches to managing a PED process and hence there was a low degree of harmonization at the outset of the exercise.

2.1 Prior research on entities internal variety and prospects for conceptual development

Before moving to the methods and findings concerning the exercise, we first review the concept of C2 variety within the C2 research and the related concept of internal variety in the IOC research.

In the C2 research, C2 variety has been characterized in SAS-143 (Alberts et al., forthcoming) as the 1) Internal C2 approach of an entity as well as 2) The harmonization options available for an entity. Ad 1: the internal C2 approach of an entity is defined by allocation of decision rights (DR), patterns of interaction (PoI) and information distribution (DoI). These are dimensions from the C2 Approach space (D. Alberts. R. Huber & J. Moffat, 2010). The dimensions vary as to how they constrain interactions, information sharing and decision making for the entities members. Overall the idea put forward in Alberts et al. (forthcoming) is that if a chosen internal C2 approach has a high degree of allocation of decision rights and allows entities to interact and distribute information freely, this will be characteristic of high C2 variety (Johansson, Carlerby & Alberts, 2018). Furthermore prior work has suggested that "agility enables one to increase the variety of the ways and means that can be brought to bear to influence outcomes" (Alberts, 2014). Granåsen et al (2011) define the related notion of C2 ability as having several more dimensions but they crucially also includes the dimensions of decision making (akin to DR), teamwork (akin to PoI) as well as information flow (akin to DoI). Ad 2: Harmonization options available is defined by the collective C2 approach, which also uses the three dimensions of within entity C2 approach space, as mentioned above, but here mapped to the interactions among entities. Additionally the harmonization options available for an entity will also characterize its internal C2 variety so that more options available will be characteristic of high C2 variety. This last aspect of C2 variety could be interpreted as overlapping with the concept of harmonization level or options. However, we see available harmonization options as the potential each entity has to interact with other entities at a certain harmonization level. Harmonization level on the other hand we see as part of the actual enacted collaboration among entities.

The research on IOC also discuss how the internal variety of an entity may influence collaboration among entities. There are numerous mechanisms for collaboration between entities. These include, but are not limited to, liaisons, boundary spanning, integration offices and orchestration (Ring & Van de Ven, 1994; Sinah & Van De Ven, 2005; Reypens, Lievens &

Blazevic, 2019). However, Schneider et al. (2017) is among the first to discuss how internal variety specifically, may influence collaboration. According to Schneider et al. (2017) internal complexity is high if the entity represents its environments as highly complex. Schneider et al. (2017) state that existing research conceptualizes internal complexity by the dimensions organizational structures and organizational processes. Internal complexity becomes relevant for collaboration among entities because organizations can make their own complexity available to other organizations through pooling resources and thus organizations collectively contribute to create a collaborative system among organizations (Schneider et al., 2017). Schneider et al. (2017) go on to suggest that the existence of collaborative complexity, i.e. the "collective creation of requisite variety by two or more collaborating organizations" fosters the occurrence of new collaboration: "available collaborative complexity generate more collaborative complexity". Schneider et al. (2017, 193) also suggest, "if there are already responses that the focal organization could benefit from, (...) creating collaborative complexity becomes a more likely option, because it is a more effective way of creating requisite variety."

Summarized prior research have developed notions of what characterizes internal variety, and there are extensive research on the mechanisms linking entities. However, we see a need to provide more depth on two aspects related to the concept of C2 variety pertaining to harmonization: *1) How entities make use of their internal C2 approach to foster collaboration with other entities. 2) Whether harmonization levels options, i.e. the collective C2 approach, available at one time could influence harmonization options at a later moment.* We now go on to elucidate the concept of C2 variety further along these lines building on the JISR case.

2.2 The exercise and methods used

To develop a better understanding of the aspects of C2 variety based on our case from a JISR exercise we employed a mixed method (Creswell, Plano & Clark, 2007). This means that different types of data were analyzed to shed light on the properties of C2 variety. We used both observational and interview data from one of the PED-cells as well as data of the communication between the entities in the exercise.

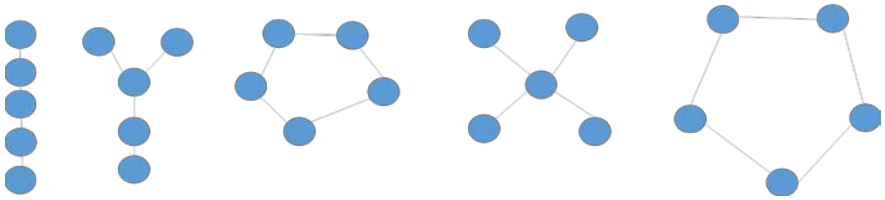
We draw on observations at one of the largest PED nodes (PED cell 20) to shed light on the first part of our examination of C2 variety, namely how individual entities make use of their

own C2 approach to foster collaboration with other entities. The method we used here can be named one of secondary data analysis, which means that others gathered the data (Frankfort et al., 1992). This technique has been used in various types of organizational research (Goodwin, 2012). Some noted problems with secondary data analysis are the relevance of the data for answering a research question, since it may have been collected for another purpose, and, related to this there may be problems in accurately interpreting the data (Wolberg, 1997; Bickman & Rog, 1998). Aligning the research data with the research question could thus become a challenge (Borgatti et al., 2013; Burt, 1983). However, with respect to the data for our analysis, the researcher doing the observations was collaborating on a project with two of the authors of this paper. Together we had defined variables of interest before he did his observations. This included examining the collaboration between the entities. In this way, the data we use are well aligned with our research interest. However, we caution that interpretations of the data were specific to the researcher doing data collection. This researcher observed the PED cell for a two-day period at the time of the UV 18 exercise and did interviews with PED cell members in this period. Williams and Shepard (2017) recommend that one defines the properties of what one wants to explore, providing an explicit way of identifying relevant information and then consider the elements of data of interest as well as constructing organizational histories. The researcher collecting the data, initially analyzed the data and the elements related to collaboration was explicitly tagged in his analysis, so we considered the relevant information to be identifiable. We read his analysis and proceeded with noting topics of interest to our question as suggested by Williams and Shepard (2017).

In addition to draw on data from the micro level of one entity, we also draw on communications data between all the entities of the exercise. An example of a static characterization of the digital communication (Request for information (RFI), ISR-requests) from the scenario shows who is communicating with whom. In order to visually present the structure of the organization and a visual analytic process adapted from (Sorin et al., 2015) was used. We present a visualization (figure 3, 4 and 5) for PED operations based on a technical Coalition Shared Data (CSD) Architecture enabling all the participants (man and machine) to take part in the PED-process. Based on the same data we also calculated the C2 approach among the entities at the three time points.

We broke down the communication data in three separate stages ('phases') with each stage being subject to a social network analysis (SNA). To be able to map the data on to the collective C2 Approach Space (of the collective of federated PED cells and nodes) a matrix was constructed identifying who was requesting information from whom, producing network diagrams, and from them, computing various network statistics. The three separate social network analyses performed on the digital communication layer produced 3 separate diameter, density and sociometric status figures, i.e. three data points (x,y,z) in the collective C2 Approach Space (for an explication of these analysis see: Stanton et al., 2009). We compared these results with network archetypes categories, the 'Chain', the 'Y', the 'Circle', the 'Wheel' and the C2 network, or edge (see figure 2). 'The y structure is characterized by a tendency toward more hierarchical interactions, unitary decision rights, and broad distribution of information. The chain and all-connected structures are diametrically opposite in the approach space as they differ along all three dimensions.' (Stanton et al., 2015, p.704).

Figure 2 Organization structures: chain, Y, circle, wheel and network (From: Stanton et al., 2015)



Specifically the three dimensions of the collective C2 approach was calculated in the following way: *Allocation of Decision rights* was mapped to the social network metric called 'sociometric status'. Allocation of decision rights was defined as follows: 'Sociometric status gives an indication of the prominence that each entity has within the network in terms of their ability to communicate with others', (Stanton et. al, 2009, p.101). Specifically, the number of entities scoring more than one standard deviation above the mean sociometric status value for a given network will be higher for edge organisations than for classic hierarchical C2. The mean sociometric status of the networks and standard deviation was estimated for the networks shown in figure 3, figure 4 and figure 5. With respect to *patterns of interaction* this dimension was mapped to the social network metric 'diameter', and the dimension *distribution of information*

was mapped to Network Density. The value of network density ranges from 0 (no entities connected to any other entities) to 1 (every entity connected to every other entity) (Kakimoto et al, 2006). Data on allocation of decision rights at the three time points was also used to test the hypothesis about the relation between allocation of decision rights at different time points. Having described the method used, we now presents key findings related to C2 variety.

2.3 Findings on C2 variety

The key findings from the analysis of observation in one individual entity, Ped_20 cell, was that the individual entity connected with the other entities, the collective, in several ways related to the three dimensions of C2 approach. Taken together we see this as ways the entity making use of its internal C2 approach to integrate with other entities and thus how the entity made use of its C2 variety in collaborating with others. From the results of the qualitative analysis, (presented in detail in Appendix A), it could be suggested that: 1) Regarding decision rights: The collective of entities are given decision rights and this is made possible by making available the individual entities resources through informing about the operational capacity. 2) Regarding patterns of interaction: the patterns of interaction among entities was working because of prior training internally of the collaboration processes to be used with other entities. 3) Regarding distribution of information: Distribution of information was working with other entities because of the cell leader managing information as well as training and pre-exercise preparation and prompt reaction to problems of information sharing during the exercise.

This analysis at the micro level of one PED cell do not provide any broader picture of how C2 variety changed over time. We now move to results at the macro level of inter-entity collaboration. These results provide some indication that the organization over time developed a more networked collaboration, and hence closer collaboration. This provides grounding for our suggestions above regarding the positive influence of C2 varietiy and its three dimensions on inter-entity collaboration.

From viewing the patterns of interaction among all entities in the collective of entities we found that it proceeded from planning, request for information (RFI's) to more dynamic tasking i.e. ISRrequests (figure 3, 4 and 5). Visually we can see a less hierarchical organizing. We assessed the patterns for task allocation, and workflow between entities (Haugen, Ellingsen &

Stensrud, 2019). The ranked graph (in figure 3) representing the initial entity set-up is based on relational data stored in a service cluster called ISR Workflow Services (IWS), and the service; Simple Persistence as a Service (SPS). Figure 3 shows the "*de jure*" hierarchy and command lines at time 1. De jure means it largely follows the pre-defined organization. Figure 4 shows the *pre-planned* communications between the entities based upon requirements for information, and this represents the collective of entities at time 2. The pattern follows to a degree the pre-defined organization (Figure 3). When comparing Figure 4 with Figure 5 we can see interaction between more entities emerging and this represents the collective of entities at time 3. Figure 5 is the *dynamic* communication, which consists of entities communicating with a format prescribed for an ad-hoc and dynamic workflow.

Figure 3. Ranked Graph representing the initial relationships (e.g. de jure organization) between the participating nodes

Figure 4. Ranked graph representing the pre-planned relationships between the participating nodes

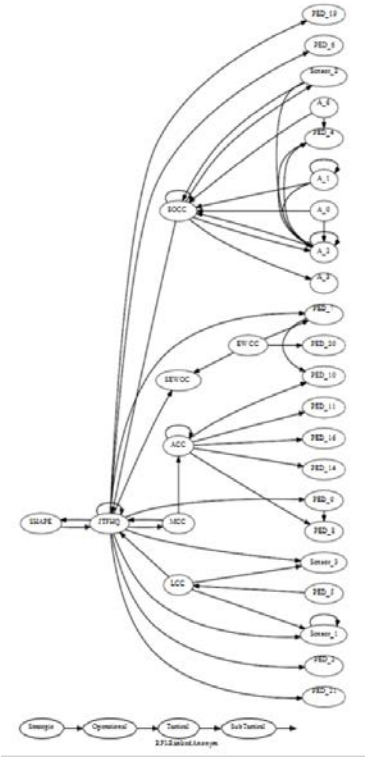
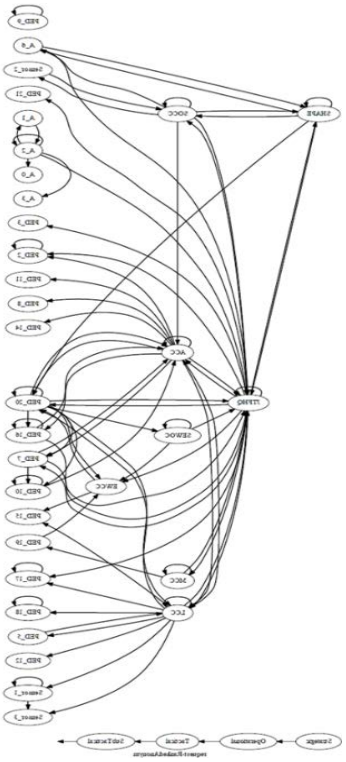
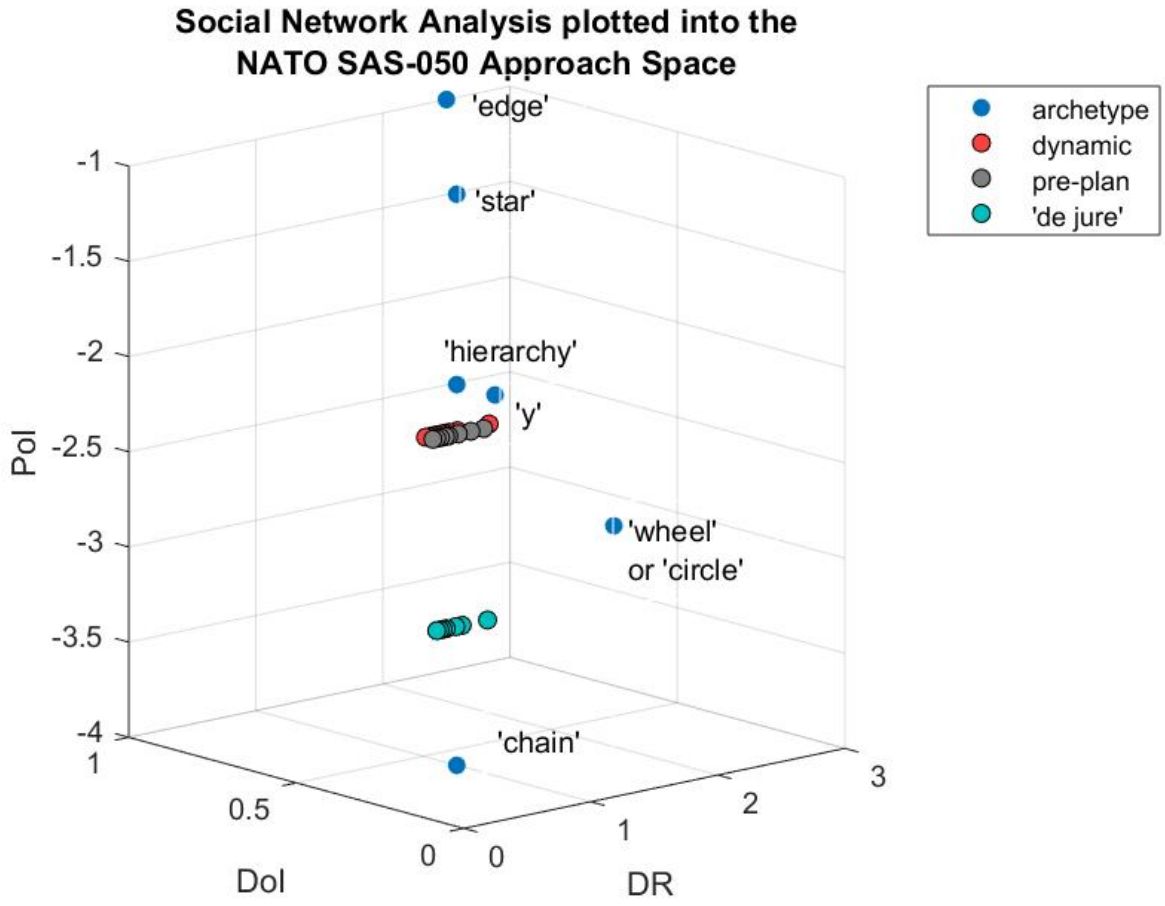


Figure 5. Ranked graph representing the emerging relationships between the participating nodes



We now depict and analyze more in depth the patterns for three time points below and plot the change in C2 approach in figure 6 (In Appendix B the detailed results from the analysis is presented). The approximate position occupied by the network archetypes (see figure 2) is also shown in figure 6 (blue annotated spots). We observed phases that were accompanied by changes in the C2 Approach of the collective of entities from time 1(de jure), time 2 (pre-plan) to time 3 (dynamic). The findings presented in figure 6 provide some indication that there was a change over time to a less hierarchical C2 approach, however it can still be categorized as quite hierarchical. Specifically it can be seen that the social network from the exercise plotted into the C2 Approach Space approximates most closely to the 'y' archetype. This analysis thus provided a more exact way to examine the organization structure than visually inspecting the ranked graphs above (figure 3-5).

Figure 6 Collective C2 approach at time 1, 2 and 3 in UV18



Our results also provided some support for the hypothesis that collaborative complexity lead to more collaborative complexity over time. To explore whether C2 variety, defined by decision rights, affected C2 variety at a later stage we tested the influence from allocation of decision rights at one time to allocation of decision rights at another time. We first examined whether the C2 approach, allocation of decision rights among entities, at time 1 (figure 3) would influence their C2 approach at time 2 (figure 4) so that there was an increased in allocation of decision rights. We then tested whether entities C2 approach, allocation of decision rights to entity, at time 2 (figure 4) would influence their C2 approach at time 3 (figure 5) so that there was an increase in allocation of decision rights. We used regression analysis to perform this test using the statistical software SPSS. The results indicated support for the hypothesis with respect to the influence from time 1 to time 2 (β=.80, p=.00) and from time 2 to time 3 (β=.70, p=.00). Interestingly the results also indicated that there are 37 % unexplained variability in allocation of decision rights at time 2 and 53 % unexplained variability in allocation of decision rights at time 3. This indicate that other factors than prior allocation of decision rights are influential in determining allocation of decision rights.

3 Hypotheses development

Having elucidated the concept of C2 variety, we now turn to develop a hypothesis about the relation between harmonization level, organizational environment, C2 variety and MDO effectiveness.

3.1 Harmonization level

We now attend to the assumptions in the research on the relation between harmonization level and MDO effectiveness. Firstly we expand on the notion of harmonization level in SAS-143. SAS-143 put forward a conceptualization for distinguishing among various approaches to, or arrangements for, C2 of Multi-Domain/Dimensional Operations. Harmonization levels are classified in levels 0-4, plotted on a scale varying from unawareness of other entities (level 0) to the integration of 2 or more entities (level 4). Higher levels are e.g. characterized by allocation of decision rights from the participating entities to the collaboration, involving more

decentralization of the participating entity. Lower levels of harmonization may only concern information exchange on a regular basis (Alberts et al., forthcoming). Furthermore: “When the highest level of harmonization is adopted, it is characterized by sharing of resources as well as extensive degree of decision rights given to the collective of entities. It is assumed that this will enhance the ability of the collective to perform collective tasks.” (Alberts et al., forthcoming). A new task group may be formed based on the entities. For the highest level of harmonization a shared, negotiated, and new C2 may be needed, which go beyond individual entity C2 (Calderon, Hinds & Johnson, 2013).

Somewhat similar Majchrzak et al. (2014) found that IOC success was related to “(a) increased use of technical team based control over decision making; (b) increasingly structuring the IOC with new roles, processes, and routines; (c) increasingly emphasizing cooperative interaction styles; and (d) an increased emphasis on a relational-based contract frame.” One of the key reasons for this suggested by the research on IOC, is that the more close the collaboration the more of the individual organizations resources can be utilized collectively by the IOC (Schneider et al., 2017). In contrast, when individual organizations pursue aims that go counter to the IOC, the IOC performance will suffer. Oliveira and Lumineau (2019) for example found that in particular conflict, behavior that is perceived as opportunistic, and dysfunctional governance structures were damaging for the IOC. Opportunism was also linked to reduction in relationship performance (Oliveira and Lumineau, 2019).

Summarized the closer and more complex the collaboration among entities is, the more of the individual entities resources can be utilized in a concerted manner by the collective of entities. Such close collaboration allows entities resource to be pooled to solve collective issues, and we therefore suggest the following hypothesis:

Hypothesis 1. Harmonization levels is positively associated with MDO effectiveness

3.2 Interaction between harmonization level and organizational environment

Although harmonization level in general may have such a positive influence on MDO effectiveness, it may be contingent on external factors. Alberts et al. (forthcoming) discusses the requirements for harmonization and the factors that enable or inhibit appropriate harmonization

arrangements from being adopted, and the costs associated with harmonization. The contingency perspective on organization design suggests that not one organizational design fits all environments (Lawrence & Lorch, 1967; Van de Ven et al., 2013). We suggest that this is also the case for collaboration among entities.

Cybernetic theory further delineate the relation between external and internal variety. Boisote et al.(2011) recasts Ashby's law as the Law of Requisite Complexity (McKelvey and Boisot, 2009) where a system, to be efficaciously adaptive, the internal complexity of system must match the external complexity it confronts. Ashby states that "a system survives to the extent that the range of responses it is able to marshal – as it attempts to adapt to imposing tensions – successfully matches the range of situations – threats and opportunities – confronting it."(Ashby, 1956,p.207) Ashby's law may be projected in a 2-dimensional space spanning Variety of response (along x-axis) and Variety of stimuli (along y-axis) representing a space named Ashby's space.

Variety of the external environment we further specify as composed of both 1) uncertainty and 2) ambiguity. We define uncertainty as the complexity and dynamism of the environment. It includes complexity referring to number of elements in the environment and number of interrelations among them (Luhman, 1975; Schneider et al., 2017) "The greater the number of elements and their interrelations, the higher the degree of complexity "(Luhmann, 1975 cited in Schneider et al., 2017). It also includes dynamism, which we see as the rate and volume of change in the environment in other words, the volatility of the environment (Dess and Beard, 1984). As for 2) Ambiguity we see as the degree to which there are different interpretations of an environment (Daft and Lengel, 1986). These notions of organizational environment is somewhat similar to Johansson et al. (2018) concept of endeavor complexity which delineate three aspects: dependencies (between components of entities of a system), dynamics (rate of change within a system) and tractability (degree to which a system is understandable (including surprising events). However, in addition to Johansson et al. (2018) we add number of elements to our definition of environment.

When the complexity of an environment is low we argue that there is less need to pool resources and to engage in close collaboration with other entities (Schneider et al., 2017). Even

though a high harmonization level will help of improve MDO effectiveness, we suggest that in many situations the close collaboration of higher levels of harmonization may not be needed for tasks that entities can solve on their own or that may be divided among the entities but do not need to be integrated. However, when there is a higher amount of elements in the environment that need to be tackled, and there is a higher number of interrelations among elements, it is more likely that resources from additional organizations are needed to solve the mission. It may also be more likely that these elements are relevant for different domains such as elements in the physical domain and the virtual domain. To manage this complexity the entities could benefit from working interdependently (Luciano, Nahrgang & Shropshire, 2020). It should therefore be seen as more relevant to collaborate with other organizations when environmental complexity is high versus when the environmental complexity is low.

When dynamism of an environment is high, one could also expect that closer collaboration among entities would be important. An example of this, is a sudden change in the type of threat facing the mission, say an imminent terror threat. In this case, a conventional army battalion may need the support of a special operations counter terrorism unit. If the conventional entity recognize the threat it can pass information to the counter terrorism unit to solve the problem, permitted that the entities engage in close collaboration with each other (i.e. the entities are collaborating at a high level of harmonization). For the counter terrorism unit to help the battalion in this way, it may need to align its goals with that of the battalion (Luciano et al., 2020). Conversely, when there is lower dynamism there are fewer specialized tasks that need to be solved ad-hoc and the entities may not thus need to collaborate as closely with other entities to solve such issues. Some prior research have indicated support for this such as Stanton et al. (2015) who found that high levels of synchronization and trust was most important when there is highly dynamic and variable conditions.

With respect to the ambiguity of the environment, this may necessitate the collaboration with other entities, for example because entities bring complementary capabilities to analyze the shared mission environment. To counter a threat in the shared mission environment it may for example be pertinent to combine effects in the physical and virtual domain because it is unclear what will be the enemy course of action. The enemy may both depend highly on physical facilities as well as virtual resources but it is unclear whether he may attack kinetically and

through non-kinetic means. It may be vital to counter both of these domains in a concerted manner. In such environments entities in the physical domain may be needed to provide kinetic effects and entities in the virtual domain may be needed to provide an effect in the cyber-domain. Multiple perspectives, which would increase with the number of entities involved, could be needed to understand such a situation (Seidl and Werle, 2018). In order for the organizations to share an understanding of such an ambiguous situation, we therefore suggest they would need high levels of harmonization. Achieving such shared understanding potentially involves transforming the entities perspectives to align with other entities perspectives (Carlile, 2004).

Based on these arguments we suggest that a high harmonization level would be most beneficial when there are high uncertainty and ambiguity of the environment. This position is further corroborated by the idea that reaching a higher harmonization level may constitute a cost (Seidl and Werle, 2018). We draw on the organization science literature, to suggest that the integration of activities constitute a cost because of the added interdependencies among entities that need to be managed and because of the limited capacity of the entities members to process information and make decisions (March & Simon, 1958; Alberts & Nissen, 2009; Lanaj et al., 2013). There may be a trade-off between making a "perfect" arrangement and the cost developing arrangement has on the entities. In less complex and ambiguous environments the cost of harmonizing may outweigh its benefits.

Based on the arguments above we expect that the level of harmonization would be even more related to MDO effectiveness when environmental uncertainty and ambiguity is high, than when environmental uncertainty and ambiguity is low, and suggest the following hypothesis:

Hypothesis 2. The positive association between harmonization level and MDO effectiveness is strengthened when there is high environmental uncertainty and ambiguity

3.3 Interaction between Harmonization Level, organizational environment and C2 Variety

While MDO effectiveness could be influenced by harmonization level and organizational environment, we also argue that these factors should be seen in light of entities own C2 variety. Again drawing on the contingency perspective of organization design we suggest that organizations internal way of organizing should align with environmental demands (Van de Ven

et al., 2013). We argue that under conditions of high environmental uncertainty the entities have to be able to utilize their own organization to the benefit of the collective in order to achieve a high level of MDO effectiveness.

The close collaboration reflected in a high harmonization level, means that there is a need to allow tasking from the collective and to enable participation in collective patterns of interaction and exchange information. We suggest that C2 variety distinguish organizations as to how well they respond to an environment and are able to engage in close collaboration. We draw on the extant literature on requisite variety in the cybernetic field and social science research (Ashby, 1956; Weick, Sutcliffe & Obstfeld, 1999) to ground these thoughts. C2 variety in the sense we use it here presupposes actively knowing subjects that are aware of the various ways to collaborate with other entities.

We use general cybernetic models to define some properties of C2 variety that would frame the utility of C2 variety for enhancing harmonization (Moody,1989 ; Doyle et al., 1982). As a starting point, the entity need to form some idea about the task it want to perform and the gap it has in terms of solving that task, a gap that may require it to collaborate with other entities. C2 variety can be a measure of the degree to which an entity is constrained in establishing collaboration with other entities. The higher C2 variety the less constrained the entity can be assumed to be. However, within this concept the idea of stabilizing own entity is critical (cf. Daft & Lengel, 1986 and Schneider et al., 2017). The entity may be able to do projection in order to foresee its collaboration, and as such makes trade-offs with respect to whether to exploit its own current internal organizing or to explore alternatives such as engaging in collaboration with other entities. We suggest that C2 variety can make the entity flexible in handling variation in the entities with which it (may) collaborate. Variation in the other entities such as their internal C2 approach, may occur between entities and over time within an entity. If there are more diversified knowledge of other entities potential C2 approach, then the requisite variety will be higher.

The type of knowledge required is further specified by Weick, Sutcliffe and Obstfeld (1999: 95) which define requisite variety in a social setting as “”conceptual slack” […] “ a divergence in analytical perspectives among members of an organization, over theories, models, or causal assumptions pertaining to its technology or production processes. […] This divergence of

perspectives is not about what the organization is doing, but rather about how it is going about it. Divergent perspectives provide the organization with a broader set of assumptions that sensitize it to a greater variety of inputs." Weick et al. (1999) suggest that the diversity of views within an entity is an important way in which social entities cope with situations. In particular it is important when the diversity reflect the fact that different members of an entity hold different knowledge (e.g. have different perspectives of the problem at hand (the endeavor), and possess the ability to adapt different ways of coping with the endeavor (an attempt to achieve a goal)).

Applied to inter-entity collaboration, requisite variety could for example mean knowledge of different C2 approaches of other entities. Such knowledge in turn could facilitate the harmonization to other types of C2 than what one normally uses in one's own entity. C2 variety may be particularly useful when it comprises simultaneously generic components (such as a general knowledge of the possible harmonization levels), specific concrete knowledge about entities, as well as ability to update knowledge of other entities. Recent findings from C2 experiments indicate some support for this stance. It found that a bespoke harmonization arrangement, i.e. one specifically designed for the mission, are more effective than an "off-the-rack" harmonization arrangement (Alberts, 2019). Thus, specific knowledge about other entities could be important. This could be knowledge about other entities in their respective domain, such as knowing particular terminology pertaining to an entity focusing on a physical domain (e.g. knowing Airforce jargon) as well as a virtual domain (e.g. knowing the particular cyber operations terminology). We therefore see high C2 variety as particularly important when there is both a high harmonization level, and there is a high environmental uncertainty and ambiguity.

If the entities have a high degree of C2 variety then there should be more reasons to believe that they will engage in solving collective problems in the IOC or the enterprise of entities, because it has a relatively small cost for the entity. We argue this is so both with respect to engaging in the collective endeavor as well as engaging in close collaboration with other entities. Conversely, if there is a low C2 variety the entity will have difficulties drawing on their internal resources to benefit the collective in highly uncertain and ambiguous environments. This is both because the entity will need to use more time to establish the collaboration with other entities and it will have less resources to bring to bear to the collective in order to solve the missions. Thus, we argue the

combination of harmonization level, environmental uncertainty and ambiguity and C2 variety will enhance MDO effectiveness and not one of the factors alone.

Summarized we suggest that when there are aspirations for high harmonization level to solve inter-entity tasks, and there is a need for harmonizing due to environmental uncertainty and ambiguity, individual entity resources also need to be available to the collective. Hence, C2 variety will further strengthen the influence of harmonization level and environmental uncertainty and ambiguity on MDO effectiveness. We therefore state the following hypothesis:

> *Hypothesis 3. There is a three-way interaction between harmonization level, environmental uncertainty and ambiguity, and C2 variety: MDO effectiveness will be most positively influenced by harmonization level when environmental uncertainty and ambiguity are high and C2 variety are high.*

4 Discussion

The purpose of this article was to explore conceptually the influence of the level of harmonization on MDO effectiveness. We suggested in part 3 that two contingencies influence the utility of harmonization level: organizational environment (environmental uncertainty and ambiguity) and C2 variety. A higher harmonization level is more positively related to MDO effectiveness, we argue, when there is high environmental uncertainty and ambiguity as well as high C2 variety. As a background for our theorizing in part 3, we developed in part 2 the notion of C2 variety and suggest that it includes three dimensions. The three dimensions are 1) the C2 approach of an entity (i.e. allocation of decision rights, patterns of interactions and distribution of information) and 2) the harmonization arrangement levels available for the entity a third aspect is also crucial: 3) the ability to make use of its C2 approach to integrate with other entities. We now note some theoretical implications, potential future research opportunities, and practical implications.

4.1 Theoretical implications

In research on C2, a crucial discussion is when different approaches to C2 are beneficial to MDO effectiveness. On a general note, the model proposed in SAS-050 of a C2 approach space, suggest

that if the mission environment is complex there is a need for a so-called edge approach to C2 where allocation of decision rights, patterns of interaction and information are highly distributed. Recently there has been an interest in examining how and when MDO effectiveness is influenced by the way entities collaborate (Alberts et al., forthcoming). We have extended this research by arguing that, the higher the environmental uncertainty and ambiguity, the more useful it is to have a close collaboration between entities. We add that in order to fully utilize the potential of harmonization, high C2 variety is also needed. In particular, we suggested that the entity must make its resources available and be able to align with procedures and exchange information. One implication of this reasoning for C2 research could be that entities in order to contribute to MDO effectiveness, will not only have to have an agile C2 approach internally, but also will have to devote attention "outwards" toward collaboration with other entities. In this way, "optimizing" one's own C2 approach may not be enough when faced with the challenge of collaborating with other entities. This means that entities will have to manage their resources by considering, on the one hand, using them within the entity and, on the other hand, putting the resources to use among the entities.

We suggest that entities do such adaptations, to a smaller and larger degree, but we did not discuss how entities make choices between inward C2 and outward collaboration with other entities. Future conceptual research could clarify this particular aspect of inter-entity C2. The question of what triggers a choice between inward and outward collaboration could be examined in future research. Increases in environmental uncertainty and ambiguity could for example trigger a perceived need to allocate resources on collaboration.

While we expanded on the C2 variety concept in a military context, future research need to tackle how to define internal variety of non-military entities and what may be similar or different to military C2 variety. In this respect, it can be fruitful to develop further the concept of internal complexity (of an organization) by Schneider et al. (2017). Specifically it could be examined how the structures and processes of a civilian organization compare to a military organization, as well as how a civilian and military organization collectively draw on their internal complexity to foster collaboration.

With respect to the research on IOC our hypotheses question the assumption that close collaboration always leads to better IOC success. While it is not novel to question this assumption (Seidl and Werle, 2018), we believe we contribute to the discussion of IOC success by specifying the influence of two crucial conditions on the utility of collaboration: organizational environment and C2 variety. Majchrzak et al. (2014) suggested a need to explore what changes of an IOC that positively or negatively affected success. For example, it may be explored whether such complex changes of collaboration as reported by Majchrzak et al. (2014) are influenced by the level of environmental uncertainty and ambiguity, and whether C2 variety, or more generally internal complexity, may help or hinder change.

4.3 Practical implications

Modern warfare and military-civilian crisis management is increasingly becoming a collaborative effort among several heterogeneous entities. In order to make such collaboration effective our analysis indicate that it is particularly useful to invest in this collaboration when there is high environmental uncertainty and ambiguity facing the entities. At the most basic it can be useful when your own entity do not have all the resources yourself to accomplish a task. At a more advanced level, collaboration allows multiple perspectives held by different entities to enrich the understanding of the situation. Some examples include allied operations where you need to collaborate at least with the host-nations military in order to successfully deploy and survive in a novel environment. In civil-military collaboration, the complexity of warfare and crisis could include famine and medical emergencies making it crucial to not only use lethal force but to collaborate with for example NGOs providing health-services. However engaging in such collaboration, when needed, is not enough: you will also need to organize internally in your own entity in a way that allows sharing resources with other entities (allocating decision rights), to rehearse and adapt to shared procedures (patterns of interaction) and to manage information and communication with other entities (information sharing).

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Appendix A

Empirical data from observation in Ped_20 cell and implications for C2 variety

Implication for C2 variety	**Empirical examples**
Relationship between allocation of decision rights internally approach and allocation of decision rights among entities: *The collective of entities are given decision rights and this is made possible by the availability of entity resources through operational capacity and no micromanagement*	"There appeared to no micromanagement during UV18 at the Ped_20 cell" (Observation of the Ped_20 cell) "The PED cell in (location omitted due to classification) was fortunate enough to be at full operational capacity during training in order to respond appropriately to all tasks." (Quote from interview with leader of Ped_20 cell)
Relationship between pattern of interaction internally and pattern of interaction among entities: *the patterns of interaction among entities was working because of training of collaborative processes internally*	"UV18 was viewed as very complex and appeared to have a greater workload for team leaders and commanders than those at the operator level. However, operational conditions for the exercise were very good in Ped_20 cell because the battle rhythm was rehearsed the week previous to the start of the exercise. (...) The PED cell leader set up additional training for his staff to ensure proficiency with all of the operational procedures (...)" (Observation of the Ped_20 cell)
Relationship between distribution of information internally and distribution of information among entities: *Distribution of information working with other entities because of the role of cell node leader as well as training and pre-exercise preparation and reaction.*	"Some systems were not interconnected. It was determined that the NATO STANAGs in place during the exercise were not enough to ensure good interoperability between nations. (...) The Cell node leader has said that it is his duty to ensure all operations run smoothly via all external communications. As well, the PED cell leader set up additional training for his staff to ensure proficiency with all of the operational procedures and use of Chat and phone systems including information acknowledgement and presentation quality for all deliverables."(Observation of the Ped_20 cell) "There were no technical issues during the exercise due to pre-exercise preparations and a reactive technical support." (Quote from interview with leader of Ped_20 cell)

Appendix B

Changes in the Collective C2 approach space dimensions in UV18

'Stage'	**Decision Rights (DR) Mapped to Sociometric Status**	**Patterns of Interaction (PoI) Mapped to Network Diameter**	**Distribution of Information (DoI) Mapped to Network Density**
'de-jure' (fig.3)	unitary (DR=0,05)	fully hierarchical (PoI=3)	tight control (DoI=0,045)
pre-plan (fig. 4)	unitary (DR=0,07)	semi distributed (PoI=2)	tight to tied control (DoI=0,095)
dynamic (fig. 5)	movement along the scale to peer-to-peer (DR=0,12)	semi distributed (PoI=2)	tied to broad control (DoI=0,11)