12th ICCRTS
"Adapting C2 to the 21st Century"

Red Force Interaction in Situated Cognition

Topics:
Cognitive and Social Issues
Network-Centric Experimentation and Applications
Modeling and Simulation

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Abstract

Efforts to maximize the impact of network centric warfare (NCW) rely upon the effective integration of human and technological agents. Combat and command and control models must represent the entirety of a network-centric organization, including both humans and non-human components which comprise any complex system. The Dynamic Model of Situated Cognition (DMSC) was introduced by Miller and Shattuck in 2003 as a tool to help analyze this kind of complex system. The model has been applied in a variety of contexts to analyze military command and control and extended and applied to areas broader than its original use. This paper proposes to extend the model by explicitly adding Red force cognitive processes. With the addition of adversary forces, aspects of information warfare can be modeled. This includes actions against an enemy's sensors and communications networks intended to reduce the quality of his information position and to disrupt the interaction between human and non-human elements of his command structure. Potential applications for the extension are proposed, including planning for and analyzing the effectiveness of 21st Century effects-based information operations against an enemy in both traditional and non-traditional conflicts.

Introduction

In 2003, the dynamic model for situated cognition was introduced in response to weaknesses in previous models to represent the entirety of a network centric organization. By explicitly including the human elements of a command and control (C2) system, it provided analysts with a means to address their capabilities and limitations as required by a complete doctrine, organization, training, materiel, logistics, personnel and facilities (DOTMLPF) perspective. This kind of complete understanding of any system or required capability is required by the Joint Capabilities Integration and Development System [CJCSI 3170.01E]. The model assumes a dynamic process and examines the interaction between humans and their non-human counterparts in the C2 process. Even though the model started as a simplistic representation of a single decision-maker, it has been extended and modified to include more complex team interactions and how sensor and network resources are managed.

Its primary remaining limitation at this point is that only friendly forces (or Blue forces) are modeled. A complete model for battlespace cognition should include the cognitive processes of enemy forces (Red forces) as well. Their cognitive processes and how those processes result in actions in the battlespace must be examined. The interaction between Red forces and Blue forces in the info-structure domain may have as profound an impact on a conflict's outcome as any interaction in the physical domain.

Review of model with extensions

The original model was an attempt to define a common framework with which groups of operations research analysts and human factors engineers could communicate effectively. It illustrates the role played by humans and their non-human entities within the command and control system, demonstrating that consideration of both is necessary to analyze true shared battlespace awareness.

As first conceived, the model consisted of six ovals and three lenses. This is illustrated in Figure 1: Original DMSC, where there is a distinction between the roles of hardware and software system elements and the roles of people-ware elements. The three ovals on the left side (Ovals 1, 2 and 3) represent the technological side of the system. The three ovals on the right side represent the human cognitive processes [Miller & Shattuck, 2004]. Oval 1 represents ground truth of the total battlespace. This includes location and status of friendly, enemy and neutral forces; as well as terrain, weather and other environmental conditions. Oval 2 and Oval 3 are always subsets of the true picture, representing sensed objects and which of those are available to users. The quantity and quality of the information is a function of sensor parameters (performance, settings, field of view, etc) and C2 system parameters (availability, capacity, etc). Not only is there a selective filtering of which parts of Oval 1 are propagated, but there is also the potential to include errors due to mistakes in sensor fusion algorithms.

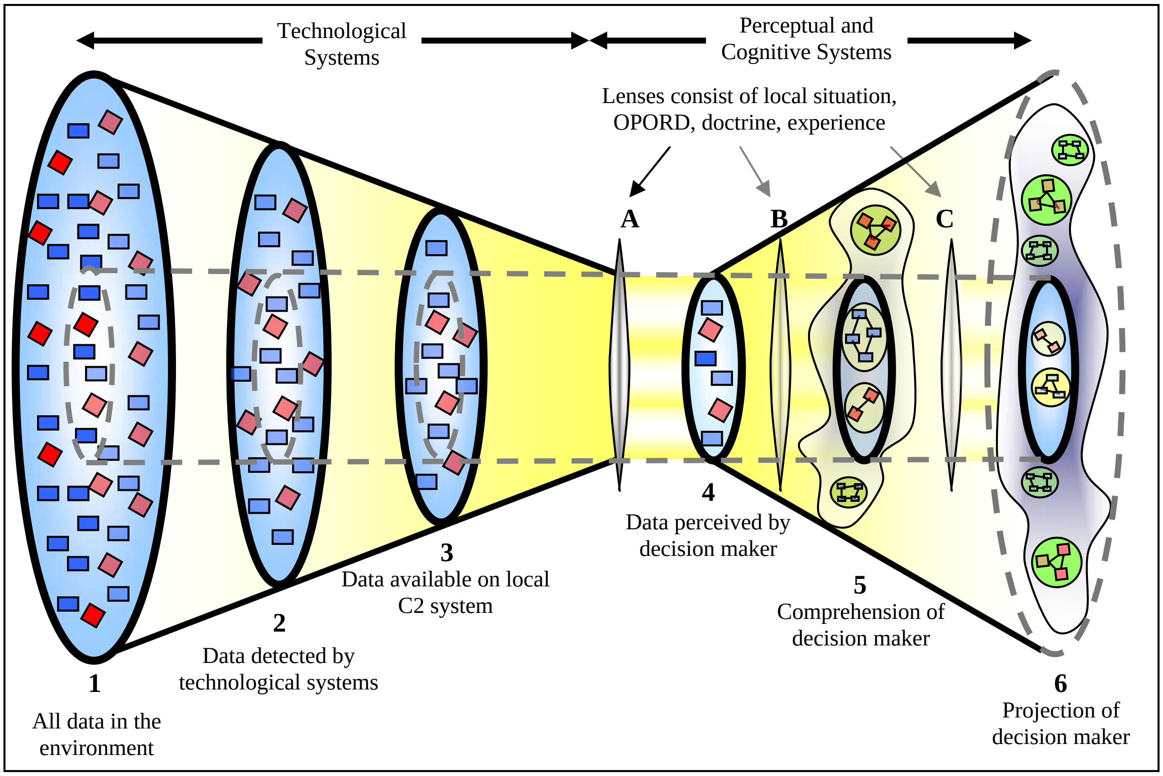

Figure 1: Original DMSC

Ovals 4, 5 and 6 on the right side of the model represent the perception of data elements, the comprehension of the current situation (sometimes called a mental model) and the individual's projection of current events into the future. Three lenses (A, B, and C) that transform the information between these last ovals consisted of the local situation, the military operational order (OPORD), military doctrine, the experience of the operator, and an individual's temporary state such as fatigue.

As with any human-based enterprise, mistakes of perception and comprehension are made. The model treats those as distortions in the lenses result in inaccuracies in perceptions (Oval 4), comprehensions, (Oval 5), or projections (Oval 6). Such errors in information transformation are illustrated in Figure 2: Lens distortions. It was recognized that once inaccurate data were accepted into any stage of the model, this inaccuracy would be propagated throughout the remaining ovals, leading to inaccurate conclusions and potentially poor decisions on the part of a force commander.

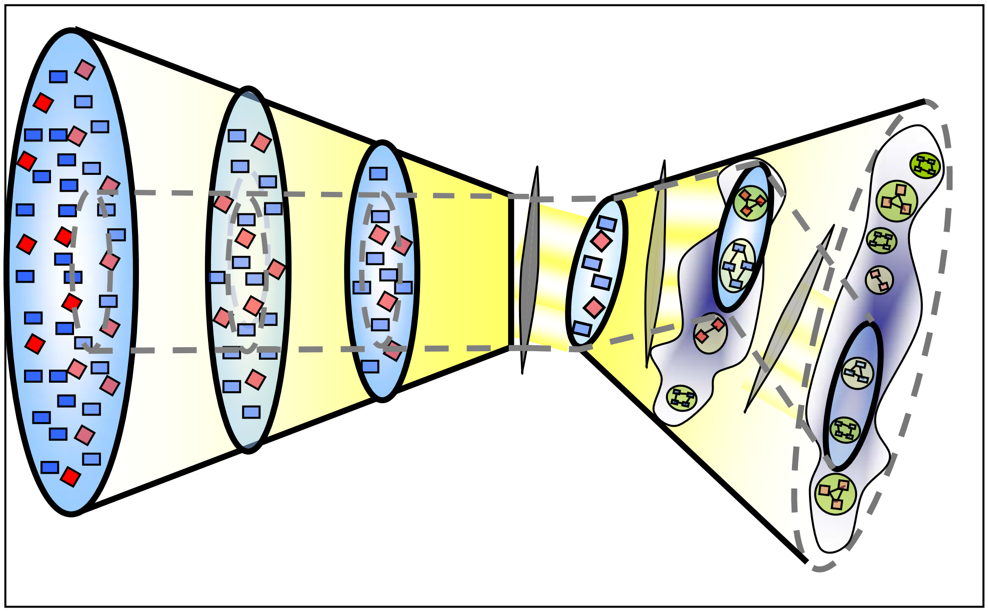

Figure 2: Lense distortions

The model can include feedback loops to represent the result of a commander's decision-making process. These decisions include direction to physical forces and management of sensor and network resources as shown in Figure 3: Oval feedback. Other feedback includes adjustments OPORD and local doctrine. This can be visualized in a similar fashion, but the arrows now point at the lenses before the ovals of perception, comprehension and projection. It is an attempt by the decision maker to reduce the distortions introduced by misaligned lenses.

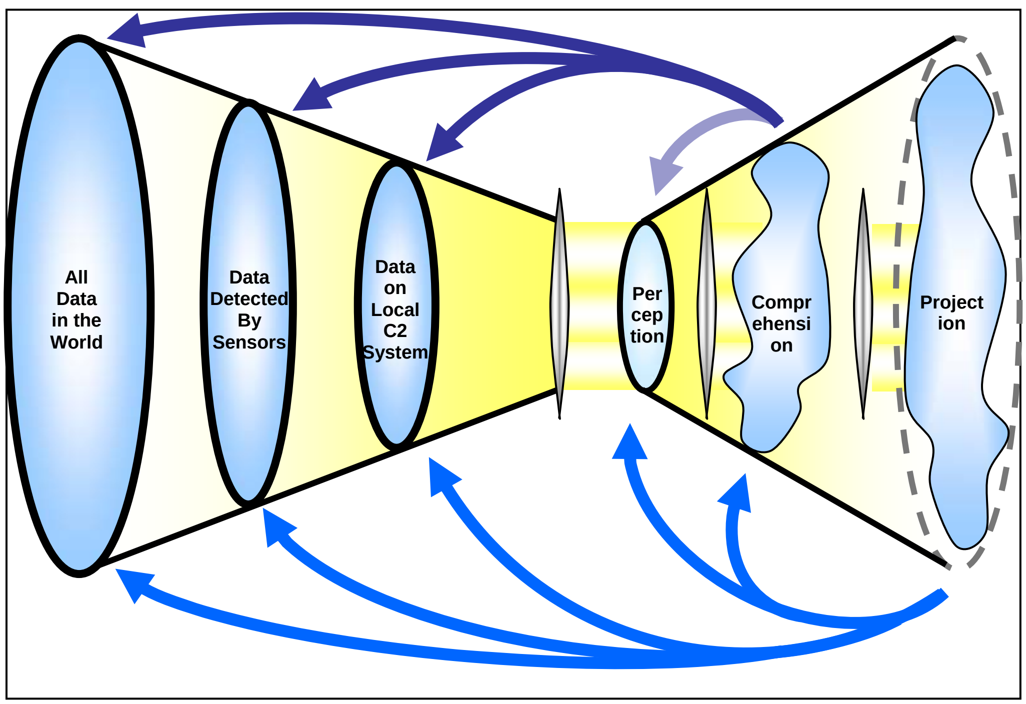

Figure 3: Oval feedback

Other extensions include team interaction in which Ovals 1 and 2 were the same for several different teams (shared), but Ovals 3 through 6 differ among individual members of the same team. The point of divergence in such a teaming environment may be Oval 2 (if sensor output is not shared) or at Oval 4 (if all participants have equal access to the shared C2 network). Direct interaction with other humans was also included by adding stick-figures just after Oval 3 and before the first lens. This injects the verbal reports from those humans into the perceptions of the decision maker along with other data available from Oval 3 [Miller & Shattuck, 2006].

A more thorough treatment of the original model, recent extensions, and current applications can be found in Miller and Shattuck, 2006. Figures 1 through 3 are from that paper.

Proposed extension

We normally designate those forces that stand in opposition to our goals in the battlespace as "Red forces" and our own (along with our allies) as "Blue forces." It would be naïve to assume our potential enemies have not considered their own C2 systems with the same rigor as we have examined our own. Now, we include Red force cognition in the model. Here, the interest is not only in the Blue force commander's perception and comprehension, but those of the Red forces as shown in Figure 4. All the previously discussed transformations of the ovals of perceptions in the model are applicable to the Red force. The Red sensors sense only a portion of the total battlespace. Only a portion of that is available on the local C2 system. In turn, it is perceived by the decision maker where the lenses of his doctrine and experience transform it into his comprehension and projection.

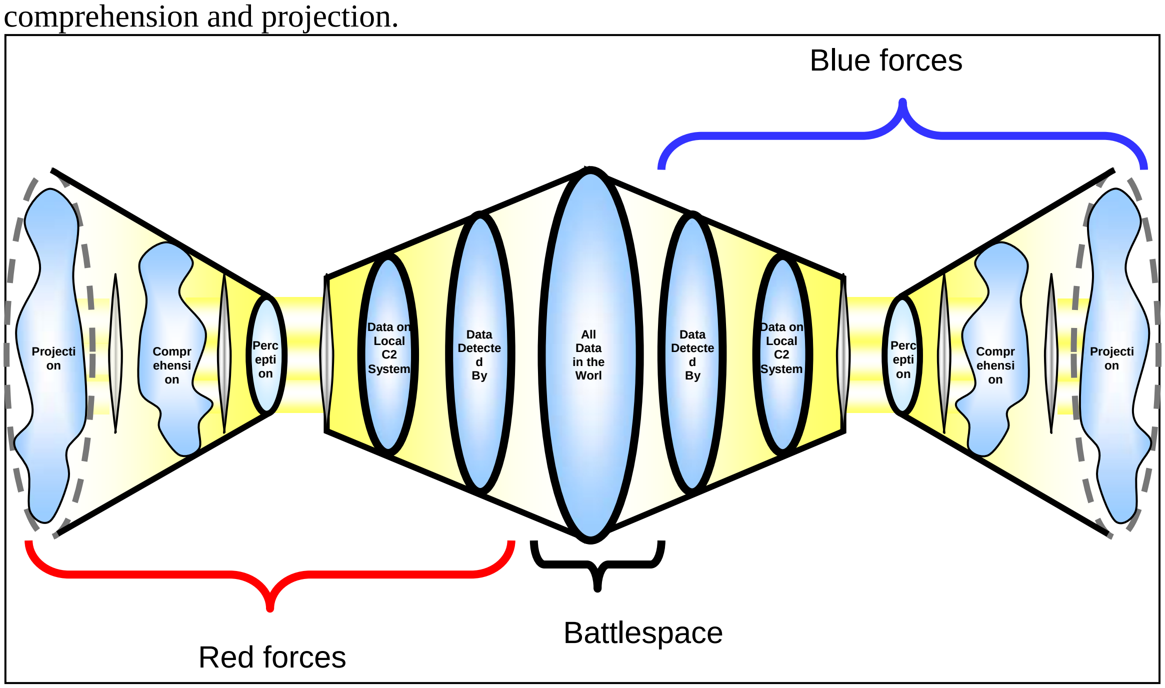

Figure 4: Inclusion of Red forces

It is important to note that Oval 1, Ground Truth, is the actual battlespace and forms the one common element in the center of this extended model. This is the true physical domain of conflict in which traditional forces engage each other.

Of course, this introduces a level of complexity not originally conceived. It leads us to necessarily rename the ovals to differentiate between those of Red and those of Blue. For example, Oval 2-Red is not the same as Oval 2-Blue because the opposing forces are using different sensors at different locations in the battlespace. Now, there are those "sensors" that are common to both Red and Blue. We all have nearly equal access to open sources such as CNN, Al-Jazeera and Debka or perhaps TerraServer. The information available via those sources would "overlap" in the second Ovals. This implies a kind of Venn diagram in which the Ovals of Red, Blue and neutral forces have areas that intersect and areas that are unique. In this model, we are most interested in those unique areas, but we should not discount the ability to introduce information and misinformation deliberately via those other vehicles. Based on that consideration, the current incarnation of the model will keep Oval 2-Red and Oval 2-Blue as separate and distinct from each other. Additionally, it implies we know something of Red's lenses of perception so they can be represented accurately in the model. This assumption may not always be valid. Valid or not, we do know they exist and have an impact on his higher-order ovals of awareness. That is, the same kind of lens distortions of Figure 2 applies to Red force decision makers.

Additionally, his decisions are implemented through the feedback control he exerts on his own forces, sensors and networks. The Red force control would appear like the control lines of Figure 3. A decision maker's actions include providing direction to his own physical forces and management of his own sensor and network resources. Of course, other feedback includes adjustments to his OPORD and local doctrine. He also seeks to reduce distortions of his lenses and make his own forces more effective.

If Red forces work as teams, the model can accommodate that functionality as well as shown in Figure 5. This particular diagram shows a team interaction in which Ovals 1 and 2 are the same for several different teams (shared), but Ovals 3 through 6 differ among individual members of the same team. The point of divergence in such a teaming environment may be at Oval 2 (if sensor output is not shared) or at Oval 4 (if all participants have equal access to the shared C2 network). This can be particularly useful when considering the participation of coalition partners and mapping their decision making processes based on shared information. There are pros and cons to designing to share at Oval 3 or at Oval 2. Further, if Red forces are composed of a similar coalition (or a more loosely aggregated band of competing war-lords), one would want to know at what level they share information so that can be explicitly modeled as well.

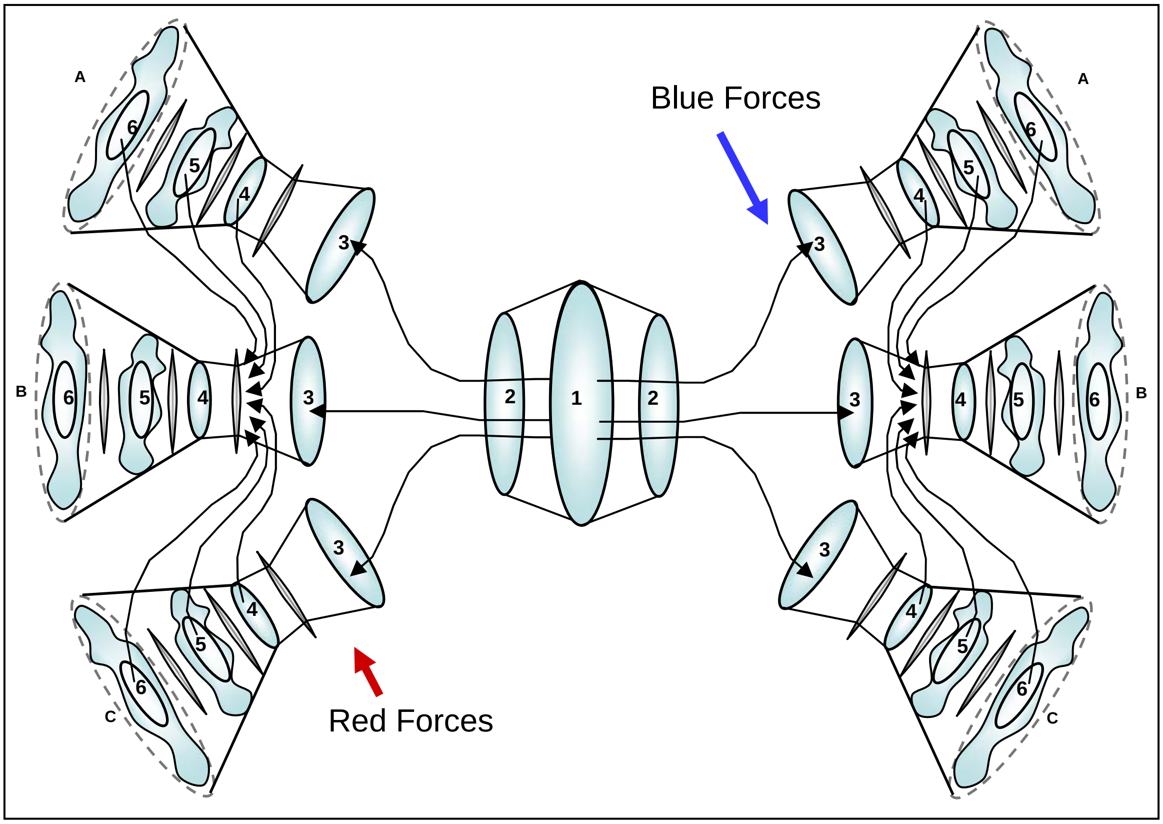

Figure 5: Red and Blue teams

Implications of including Red forces

If we have specifically included the comprehension and perception of the Red forces, the next logical step is to include offensive information operations (IO) against him. In the broadest sense, IO includes actions taken across the spectrum of adversarial relationships, from competition to full-scale conflict. IO can involve covert action against a competitor's political, economic and physical infrastructure. Thus, it can allow national objectives to be achieved across the spectrum of conflict [Schleher]. However, the current work focuses only on command and control warfare. That is, the operations against military decision makers and their command and control systems. The goal of C2 warfare is to reduce the enemy's ability to gather and manage information on the battlespace and make decisions based on that information that will influence the outcome of the total conflict. This is a worthy goal in modern warfare. One might even argue it should be the *only* goal. It is not Red's actual means to resist Blue's objectives that is the target of action in the information age. Rather, the true and correct target is Red's *perception* of his means to resist. His decisions are based on his perception of the situation, his alternative courses of actions and his projection of those alternatives [Waltz]. If Red's perception that all his viable options will lead to results counter to his own goals, he will have little choice but to behave in a way consistent with Blue's desires.

However, Red, like Blue, is seeking to gain a position of information superiority and then leverage that position to create and maintain his own competitive advantage [Alberts, Garstka & Stein, 1999]. Our goal is to reduce the quality of his battlespace information. If we define the quality of that information in terms of its timeliness, relevance and accuracy; any action taken by Blue forces to reduce one or more of those attributes is considered C2 warfare. In the same way that arrows were added to the original model to represent feedback control of one's own forces and management of sensors and networks, we have added arrows to represent offensive C2W as shown in Figure 6. The arrows do not represent specific *means* to affect the flow of information, but the influence of the action on the content of the ovals.

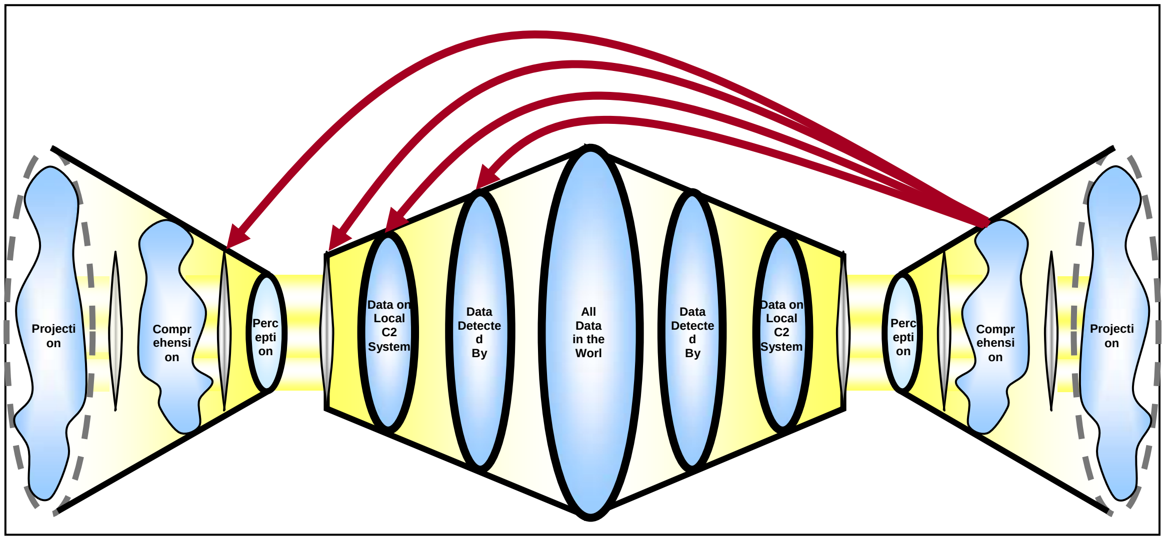

Figure 6: Offensive C2 Warfare

Counter-sensor warfare is aimed primarily at degrading the quality and quantity of information at Oval 2. It includes classic electronic warfare such as jamming intended to deny the proper operation of sensors and deception intended to introduce false signatures. Traditional signature reduction minimizes a physical asset's observability. The use of expendable decoys and even physical destruction of an enemy's sensor assets should be considered. The common element here is an attempt at reducing the quality of data detected by technological systems. As such, one would expect actions to be technologically-centered vice human-centered. Similarly, electronic warfare aimed at disrupting communication links and networks degrades the quantity and quality of information available at Oval 3. That is, the information gathered by the sensors (Oval 2) is made available to human operators, and Blue forces want to impact that process. The value of representing both Oval 2 and Oval 3 in this context allows the designer of a complete information campaign to consider the potential interaction between the two. If Blue introduces false signals and decoys, he would want that to propagate to Oval 3 while not allowing the propagation of information in Oval 2 that might reduce the effectiveness of such deception.

We should also revisit the concept of feedback loops. These loops represent the result of a commander's decision-making process, with regard to directing physical forces, management of sensor and network resources, and adjustments to OPORD and local doctrine. Forcing mismanagement of sensors or networks may have as great an effect as an attack on the network or sensor itself. This kind of disruption can now be added to the model as illustrated in Figure 7.

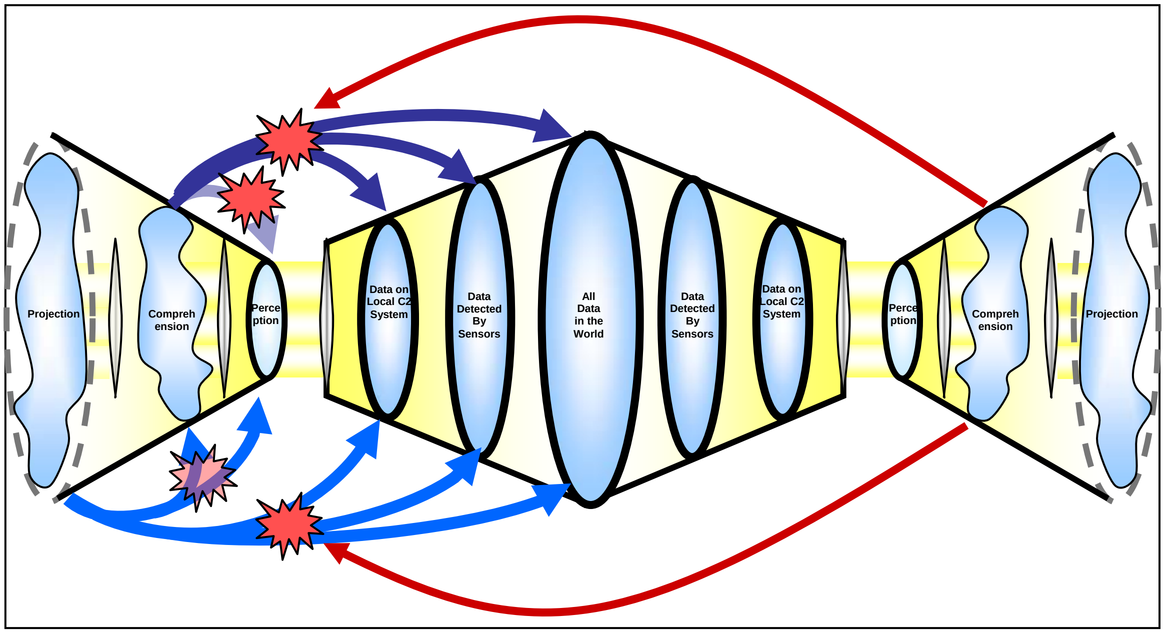

Figure 7: Disruption of Feedback

A more complete consideration of counter-communication warfare requires us to examine the influence of geographically-dispersed players in the C2 process. If we consider our opposition's use of teams, we must focus attention on those links that enable sharing of perception, comprehension and prediction between entities A, B, and C.

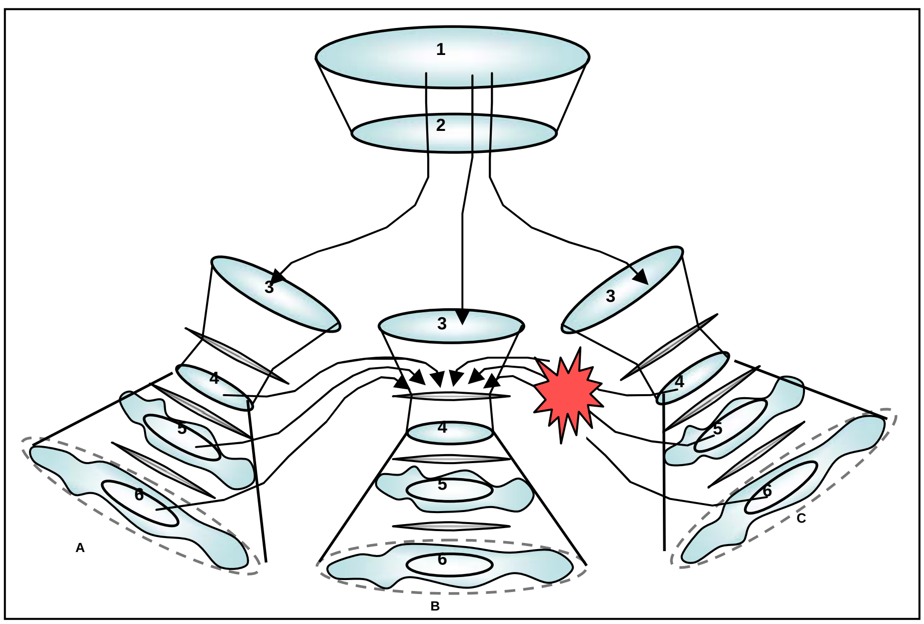

Figure 8: Anti-communications efforts

Information operations can now be more specifically aimed at anti-communication. The ties between entities are severed and kept disconnected as shown in Figure 8. While the same anti-network warfare mentioned previously could negatively impact any network infrastructure, the goal here is specifically to reduce Red forces' capability to share knowledge and collaborate which will prevent any effective self-synchronization. Injecting false or deceptive information into the information net (at Oval 3) would have a similar effect. An attacker could choose between jamming the information recovery circuit or the synchronization circuitry. Causing a loss of synchronization may be more effective than causing errors in information symbols. Either way, affecting even a relatively low bit error rate will virtually deny the use of a typical tactical data link [Schleher]. One could even now consider introducing different deceptive information – one picture tailored for entity A, another for entity B, etc. If a truly networked force relies on those connections and resulting self-synchronization, the results could be anything from delays in spares and supplies delivery to lethal Red-on-Red engagements. Indeed, as all organizations are vulnerable to failures induced by internal power struggles, one could introduce information enhancing the negative effects of such conflicts [Kott]. A little distrust and gossip could have a dramatic effect on the organization's function.

And, of course, we include operations aimed at Red force lenses of doctrine and OPORDS to introduce distortions in perception and comprehension. The entire spectrum of deception, psychological operations, and all means to impact human-centered aspects of cognition can be mapped into this model extension.

The next logical step may overstep the traditional behavior intended by the original model. However, it is included here as a means to further visualize the potential uses of including Red forces. Given that humans have been added to the model as providing direct verbal (or similar) reports to a decision maker, it seems appropriate to explicitly indicate how Blue forces can influence Red force behavior through that venue. Figure 9 is a first attempt at including this kind of C2 warfare in the model.

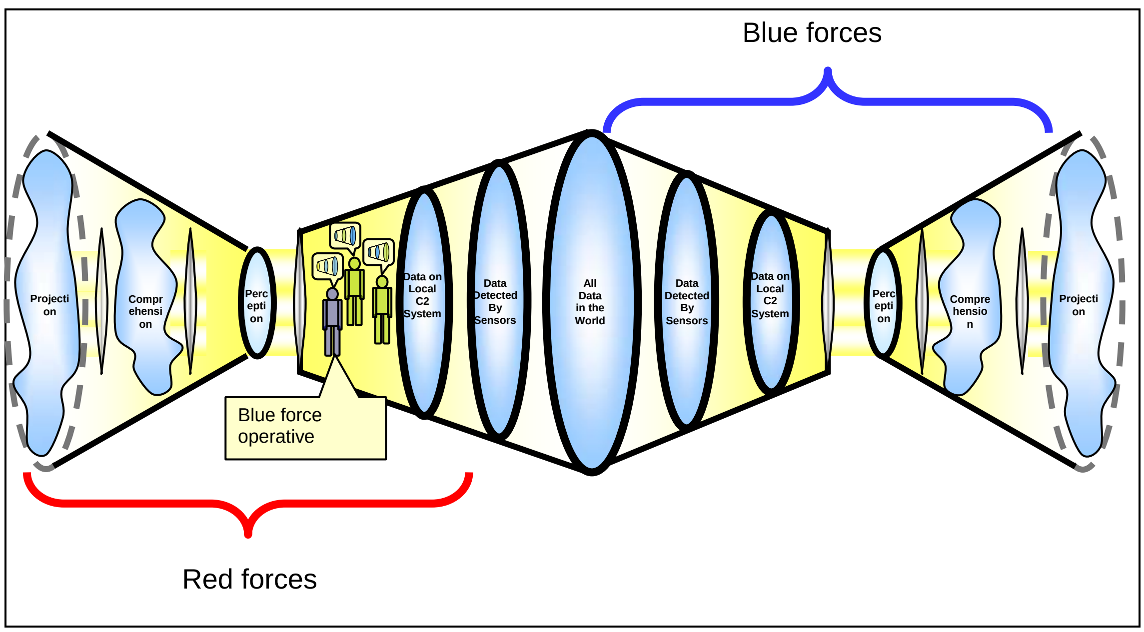

Figure 9: Blue and Red direct human interaction

One of the model extensions explicitly included human actors interacting with a decision-maker by providing input at Lens A [Miller & Shattuck, 2006]. That input is from those actors' Ovals 4, 5, and 6 – representing their own perception, comprehension or projection. That is depicted by the "voice bubbles" of those stick-figures in the model. It is first filtered through Lens A along with the perceived information at Oval 3. A Blue actor could be covertly inserted with the others and his mis-information could potentially have an influence on the decision-maker with equal weight as Red's own team members. That is, Ovals 5 and 6 would be corrupted. It should be noted that this extension appears to be least helpful in current experimentation and modeling efforts. However, its usefulness may become more apparent in time. One should also keep in mind that this interaction does not necessarily require physical contact between the actors. Telephone conversations, text messages, on-line chat are all included.

Potential Applications

As the original model has been used to model the flow of information in military decision-making processes, this extension will be used to model how degradations in information quality or quantity affect those same decisions. In this case, one would be most interested in quantifying the impact of degradation in information and information sharing on the overall force effectiveness. The dynamic interaction among all battlespace actors (friendly, adversary and neutral) is a key element in analyzing C2 effectiveness [NATO COBP]. It is clear from the original model that information goes missing or is corrupted as it "transfers" between ovals as a result of limitations in sensors, networks or the commander's "lenses." Naturally, those limitations could be exploited by an enemy. Inclusion of Red forces means his actions against Blue forces can be considered. The scope of the model should remain focused on the sensor-to-decider chain. That means we are only including Red and Blue force C2 warfare. All sensors and communications systems are legitimate targets for physical destruction, temporary disruption or deception. It allows us to more effectively identify our own systems' weaknesses and propose defensive C2W solutions. Indeed, the United States Joint Forces Command considers severe degradation or loss of information networking as the highest risk to effective C2 [C2 JIC]. The user-centered design principles that made the original model so useful are maintained here. Additionally, as with the original, any size force operating at any level of warfare or operations can be modeled. That makes the inclusion of adversary forces particularly useful whether considering operations against a near-peer competitor in traditional conflict or non-state entities in an asymmetric scenario.

Measuring the effectiveness of C2W is as challenging as measuring the effectiveness of any C2 system itself. Ultimately, the end-users are concerned with high-level measures of force effectiveness or even measures of policy effectiveness. The latter set of measures is most applicable in operations other than war (OOTW). That is, actions that could be highly effective in "winning a war" may be counterproductive in a mission such as disaster relief and humanitarian assistance or in civil reconstruction. It becomes a question not so much of physical effects, but how actions are perceived by actors in a region [NATO COBP, 2002]. We then propose to begin with the measures of C2 effectiveness as supporting the higher level measures of force or policy effectiveness, which have been discussed in several sources [Bornman, McCafferty and Lea, C2 JIC]. The effectiveness of our C2W against Red forces is then tied directly to the *in*effectiveness of his C2 systems. That is, we are interested in our ability to counter Red's ability to develop and maintain shared situational awareness and understanding.

One would examine how well he can present tailored, relevant, synthesized, actionable information to promote understanding [C2 JIC]. That metric could be composed (in part) of an objective measure of Red's information's *lack* of timeliness, relevance, accuracy and accessibility following Blue's initiation of some C2W action. Other measure might be the percent reduction in Red's decision capacity and accuracy or the delay introduced until decision [Waltz].

The proposed extension implies that only top-down, commander-directed C2W actions are allowed. That is not the intent. As all actors in a battlespace can act in self-synchronizing ways, the application of C2W should be viewed in a similar context. That is, actors with electronic and information-oriented effectors can apply them based on a shared understanding of the commander's intent and shared battlespace awareness with their peers. Even in a classic, non-network-centric system, the sensor-decider-shooter chain should be shortened by allowing those individual engagement systems with autonomous search capability to engage enemy elements in time-critical situations [MacFadzean]. In the information age, that engagement can be varied in its incarnation, but with its essence always focused at influencing an adversary's perceptions and projections. Indeed, this model is intended to capture the C2W interaction at any level of warfare at any level in a decision-making organization. That is, Ovals 5 and 6 "belong" to anyone with the capability to direct offensive C2W, from a single air-defense battery to a combined force commander. Care must be taken to consider the effects of those operations at the right level, too. A tactical-level application of counter-sensor or counter-communication action could very well have a strategic-level impact. This implies that the C2W rules of engagement and that at least a theater-level C2 campaign plan be a part of the commander's intent. Information weapons and C2 weapons should be applied not with complete anarchy, but with the precision required of any physical weapon. One must prepare for and manage C2W actions, from target nomination through weaponeering and finally attack with battle damage assessment [Waltz]. Particularly with deception planning, the careful application of multiple actions should limit the target's ability to access and compare multiple sources so that the possibility of detecting the presence of deception is minimized [Kott]. This model should be used in that process to help plan and execute a C2W.

Conclusion

The proposed extensions of the Dynamic Model for Situated Cognition are an attempt to increase the robustness, flexibility and breadth of applicability of the original. Event analysis and predictive modeling efforts of network-centric forces opposing each other in the battlespace can be aided by this tool. The extension shares all the advantages of the original:

- Realistic information flow is represented in the operational environment, including its collection and dissemination, and eventual use. Lost information, mistakes in judgment and the impact of the human element is clear.
- Commander's decisions are represented explicitly, and are based on his perception of the battlespace.
- It is flexible enough to be applied across the spectrum of military missions and tasks.

- It is adaptable enough to be used at any level of warfare and for any size organization.

Additionally, it brings more advantages with it:

- Opposing commanders' perception is explicitly represented, which allows the effects of information operations to be considered. The "ripple effect" of processing degraded information from lower order to higher ovals is clear: inaccuracies in the commander's perception and projection.
- C2 systems are represented as entities in the operational environment. They can be targeted just like any other entity. Their ultimate utility is in their ability to enable decision-makers to take action.
- Information operations for opposing forces are explicitly included. Deliberate attack and protection of C2 systems allows us to model degradation in the quality of the adversary's information and how that impacts his decision-making process.
- The focus is on *what* the attacker intends to accomplish with his actions against an adversary's C2 systems rather than on the *how* those actions will be accomplished. Form should follow function. The objectives of C2W should be established before considering an adversary's vulnerabilities and corresponding points to apply deception or denial, consistent with any other effects-based operations planning and execution.

The extension is now more consistent with C2 modeling guidelines provided by NATO [NATO COBP, 2002]. Information operations and C2 warfare are not new, but including them in the dynamic model of situated cognition promotes understanding their impact on adversary decision-makers.

However, this is just the initial proposal for these extensions. Their ultimate utility can only be proved through the various venues already taking advantage of the original, including laboratory and field-based experimentation. The goal is to provide system designers and campaign planners with an aid in their efforts to realize the full potential of network centric warfare and the precision control of perception.

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