Multi Domain Command and Control (MDC2) an Execution Concept

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Abstract

There has been outstanding effort describing the expected conceptual outcomes of Multi Domain Command and Control (MDC2). The challenge has been transposing the conceptual language into executable output products, as efforts have shied away from overall global improvement in Command and Control (C2). Improving data flow/storage and improving C2 are conjoined sets, but not overlapping conceptual sets. Information flow is made up of both noise and signal. It is not the volume of data that matters, but rather the signal that matters. Having everyone share a gigantic common “data lake” or even a commonly replicated “data ponds” does not by default, make better fisherman of information seekers. Just as pushing more data into one end of any comm pipe, database or someone’s cloud with the hope the operator will somehow extract just more signal on the other end is not a valid assertion. The goal of this paper is to use the lens of C2 theory, Air Force history and cutting-edge technology to see what can be accomplished to improve global C2 in an MDC2 world. This paper attempts to lay out an execution vision regardless which of the four classical program advancement techniques any solution providers decide to use. Therefore, a sub goal of this paper is to simplify the operational vision of the future MDC2 to help the acquisition community to provide the first physical version of the MDC2 quicker, cheaper and with all needed military capability.

Key Words: MDC2, Multi Domain Command and Control, C2, Command and Control
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I like to say without communication, all I control is my desk, and that is not a very lethal weapon. – General T.S. Power, CINCSAC, May 1958

A precise answer to the wrong question can be more harmful than an eclectic answer to the right question. The wrong question to ask about the Command and Control (C2) domain is how to best line up all the computer systems, databases and applications to achieve the reality promised in the marketing phrase, ‘the right information, at the time, and at the right location in the right format.’ This phrase is misleading on three counts: the sales pitch defines a priori information as equivalent to a posteriori information; this carnival worker’s call implies global data coupling in which all information has the same pedigree (level of validity, level of security, level of availability, level reciprocity, etc.); and that data will be shared ubiquitously. Information age warfare will be different from industrial age warfare, but not in the way defined by a wishful marking supposition:

The war, as any other human activity, is a product of its age, its weapons and strategies permanently evolved in the same time with the technology development. The future war in the “information age” embeds the unique characteristics of this period, thus being different than the other types of war previously conducted and affecting the operation capabilities and the nature of the conflict environment. (OPREAN, 2012)

The future difference may be as great as or greater than the difference between agrarian age warfare and industrial age warfare. Air power has worked to achieve the operational objectives in the last five US wars and be expected to lead deep within the information age. Command and Control is the key enabler that allows air power to execute as a tool of national military power.

There has been outstanding effort and many publications relating to the expected conceptual outcomes of Multi Domain Command and Control (MDC2).

“Multi Domain” is the word du jour of the defense enterprise. … There are a lot of smart people trying to wrap their heads around what this means for the employment of

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forces, but much of this churn is currently wasted, as the defense community does [even] not have a basic definition for the word “domain.”  

A continuing challenge has been transposing the conceptual language of MDC2 into executable output products. Current efforts have tended to attempt to describe improvement of nodal technical flow of data between organizations instead of overall global improvement in macro C2. Improving technical data flow and improving C2 are conjoined sets, but not overlapping conceptual sets. Information flow is made up of both noise and signal. It is not the volume of data that matters, but rather the signal that matters. Having everyone share a gigantic common “data lake” or even commonly replicated “data ponds” does not by default, make better fisherman of information seekers. Just as pushing more data into one end of any comm pipe, database or someone’s cloud with the hope the operator will somehow extract just more signal, which he may desperately need, on the other end is not a valid assertion. The goal of this paper is to use the lens of, C2 theory, Air Force history and cutting-edge technology to see what can be accomplished to improve the C2 of the “trigger pullers” in an MDC2 world.

The actual air power C2 system exists only when engaging an adversary. The actual system is a combination of the people and infrastructure in place accomplishing a military mission. Between C2 theory and C2 operations stands C2 Systems. According to Maykish (2014), “C2 history shows that C2 theorists navigated megatrend-type changes while gaining insight into C2 fundamentals at the same time.” His supposition results in the following chart:

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The sub goal of this paper is to begin to sort through the “uncertainty” that currently defines Maykish’s Stage 6 that is being reflected in the ongoing implementation of Multi Domain Command and Control (MDC2).

It is well recognized that traditional software development and acquisitions cannot keep pace with changes in operations or advances in technology. Commanders desire rapid development of new capabilities for the current fight and to outpace near-peer competitors. New and emerging capabilities take too long to be integrated and fielded into the AOC WS* enterprise. Within the human experience there are only 4 ways for any program to advance. The first recognized technique is “trial and error”. Trial and error method is use effectively by nature, but with a recognized Weapon System can be costly and time consuming. The second technique is to move along a defined process. The acquisition system (DOD 5000) is a defined process and

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programs can track their progress (both success and failure) using terms and process defined in the 5000 series documentation. The 3rd procedure would be to use historical precedent (both verbal and/or written) and this method is well demonstrated in ship design. The last technique is to use theory to guide program advancement. This technique is appropriate to advance into the unknown and was used by Manhattan Project. The AOC WS program has struggled since inception to integrate a large number of IT systems into a coherent architecture that can be configuration controlled, modernized, and sustained. It should be expected MDC2 will undergo similar challenges as the current AOC. One likely cause of this Chimera of issues is military need is not always resolved with available technology. It took almost five years of development and integration before COMACC declared AOC Block 10.1 Initial Operational Capability (IOC). AOC Block 10.1 has been placed into sustainment and resourced to focus on security patches and version upgrades driven by cybersecurity requirements. An additional sub goal of this paper is to simplify the operational vision of the future MDC2, encouraging the acquisition community not to repeat the problem of the AOC, but to provide the first physical version of the MDC2 quicker, cheaper and with all needed military capability. Therefore, this paper attempts to lay out an execution vision regardless which of the four classical program advancement techniques any solution providers decide to use.

C2 Theory

The biggest differences between a mob and a military is organization and discipline. Often the term C2 is used without a true understanding what is means. To provide a common understanding C2 I am starting this paper with a review of the theory of C2 (decision rights, pattern of interactions, distributing of information). More data, more systems, greater complexity, does not by default change C2. Command is about the art of human interactions whereas Control is more about the science of sharing communication. Command and Control (C2) theory, to remove military prerogative and commander variability, assumes if all share common understanding of the reality in question, everyone will self-synchronize their activities maximizing the effort of the whole. The execution of any Multi-Domain C2 (MDC2) force will need to orchestrate a heterogeneous set of entities and operations to ‘synchronized’ kinetic and non-kinetic effects across different defined domains categorized as physical, virtual, and cognitive/social domains or Air, Space and Cyber or other conceptually bound sets. The term for self-synchronizing defined organizations in C2 theory is “Edge”. The C2 approach space\textsuperscript{4} has been established by the community as depicted below:

\begin{itemize}
\item See Supplemental if unfamiliar with AOC WS.
\item Alberts, David S. (David Stephen), 1942-
\item NATO NEC C2 maturity model / David S. Alberts, Reiner K. Huber, and James Moffat. Feb 2010 available at www.dodccrp.org
\end{itemize}
It should be noted the scale for Allocation of Decision Rights, Pattern of Interactions and Distribution of Interactions should not be assumed to be mathematically linear. The recognized areas (Conflicted, De-Conflicted, Coordinated, Collaborative, and Edge) are conceptual. Even though this C2 model is conceptual, technical elucidation can be extracted. Example: If the number of organizational boundary crossing interfaces, the ports in a firewall, Quality of Service (QoS) or varying number security level networks (NIPRnet, SIPRnet, JWICS, etc.) decrease; the resulting C2 will vector away from Edge and move towards Conflicted as less transmission resources are available (i.e. a decrease in Interactions and Distribution). What is well known is - if transmission/communications paths become “zero” operations by definition will become “Conflicted”.

Any electronically stored, transmitted, or recorded data is neither information nor knowledge. Humans must provide the mathematically defined and physically manipulation of electrons context. Humans deal with information, at the current level of technology all non-human entities (machines/computers) can only manipulate data. Ubiquitous use of the term “information” within the MDC2 blurs that critical distinction. The expression “Information/Data” would provide clarity, but does not fit well on most slides. I would propose using the term “Info/Data” across the MDC2 program to express the embedded duality of work supporting both humans and machines.
Common understanding and Situational Awareness (SA) is not provided by the Common Operational Picture (COP) that machines display on someone’s computer or wall, but the common understanding and interpretation of the real external milieu is contained in the minds of individuals within an organizational structure. Humans are self-organizing, problem-solving creatures. Operators looked at closely as a group, show great variability in how each of them performs their perceived tasks. Humans (i.e. wetware) in a social-technical organizations have known recognizable limitations. At any given time, the human short-term working memory ranges from approximately 7 + to –2 objects. The higher the abstraction an operator uses, the lower the number of objects about which he must think. For example, it is easier to think about a car than to think about the parts in a drive train, or all the parts in an engine, or what is happening in each cylinder on each stroke. Moving up the abstraction level reduces workload and facilitates the transmission of concepts to other human operators operating at a similar level. In addition, machines can pass a great amount of data; humans as communication channels are extremely limited. Our bandwidth is less than 100 bits/second (Nørretranders, 1991). Nørretranders' concept posits that a sender starts with an idea that he wants to communicate. He consolidates this idea in language through models and metaphors. If the receiver shares the same models and metaphors, he or she will comprehend the information and its underlying associations.

The last subsection of C2 Theory that needs to be examined is the continuum between the concepts of system Integration and fragmentation. When differentiation is one’s strategy for success, fragmentation will happen. In natural systems, we see the differentiation/fragmentation process happening in insects and animals with the creation of different genus or in the evolution of an entirely new species. In man-designed systems, the process is often replicated; one need only observe the many different one-off, spinoffs, rip-offs and other-off’s of any truly uniquely beneficial design, product, service or concept. System fragmentation/specialization can have benefits, like lower nodal cost, but at the same time, it brings a range of complicating problems. Here are two classic military examples: (example 1) Traditional industrial age militaries can divide into organizational blocks, and when defined blocks fail to function as expected, the organization can reorganize, rearm, and reequip as needed (resulting in fragmentation). In the Information Age, with (example 2) massive amounts of static infrastructure is required to move data, will any new organizational structure be more than deck chairs on the Titanic –unable to quickly remove from battle and rearm/reequip (respond to fragmentation)? Industrial Age systems were divided along the specialty functions; the army got the tanks and the navy got the ships. Should that same philosophy be used in knowledge intensive management organization? In the AOC, should each of the five divisions, or maybe even all of the specialty teams, have their own unique applications and systems, or be supported by multiple systems or should a single integrated system be use? If a single large system, it should be remembered that in 1991 a single mistyped character in a single line of code knocked 12 million customers of AT&T offline. Conway's law (organizations which design systems ... are constrained to produce designs which are copies of the communication structures of these organizations) may influence the final design.
Continuing Essential Principles of Command and Control

At the current time the US Air Force and society at large is undergoing a fundamental shift as Information Technology (IT), processes and expectations collide. As we move deeper into the Information Age we can expect more and larger clamorous events to shape the Command and Control (C2) world. It is important to understand the continuing principles of C2 and when guidance is not available and bind our decisions to those principles. Warfighters need to define how available and future tools should be used to support military operations. When we have allowed our technologist to define the future we have ended up sending fighter aircraft to war without an internal gun and requiring 5 switch actions to shoot a missile. Anything that can be done to increase interoperability (without overwhelming the humans) is most likely a good thing. At the core of interoperability are technical standards that define how each arrow or lightning bolt on some PowerPoint Slide will actually becoming a conduit for data movement. An F-22 and a B-2, or any other link and node construct will never share any information/data unless there is at least one common technical standard or path through several standards. Because of shared standards the ubiquitous worldwide communications is fragmenting and increasing the rate at which data grows, and is shaping how data flows through our systems. No matter what happens with technology in the future, the Essential Principles of C2 learned through the school of hard knocks, will remain constant.

1) The highest risk to any Command and Control (C2) machine (hardware/software/network) capability is that the best selected solution today will become tomorrow’s orphan technology. The lower in the technology stack where the work becomes abandon it should be expected the cost of recovery will be exponentially larger. In an environment of increasing creative destruction of technology, orphan technology risk is very high. To mitigate the risk of orphan technology, critical technological decisions should be expected to use “largest market share” as criteria for product selection. The implied cross constraint of “lower cost” should only be acceptable within limited bounds and cases supporting an overall reduction in military risk.

2) As mentioned previously, System theory points to the fact that all systems, as they change over time, will move in the direction of fragmentation and differentiation (Kast & Rosenzeig, 1985). System theory also tells us that all systems will experience a counterbalancing imperative to seek integration and convergence to cover the common principles that underline their functioning. (Katz & Kahn, 1978). System fragmentation is the “ugly baby” in C2, not because it is going to happen, but because no one truly knows how best to management it in a knowledge age.

3) Nodal optimizing C2 with the assumption global optimizing will result. Global optimization is the task of finding the absolutely best set of conditions to achieve your objective. A local optimal is when the systems value is based on internal measure of progress or a measure against nearby systems. We must seek to measure against global C2 results vise simple local improvements to achieve systemic improvement. Many of those global measures can be extracted directly from current C2 theory.
4) Communications can never be 100% pure information. All systems transmit both noise and signal. In general, a tightly coupled system represents a localized Van Neumann architecture whereas an on premise or off premise cloud architecture is a distributed construct of the same fundamental architecture. There is little hope that a pure tightly coupled system architecture and true cloud architecture can coexist. In most cases the difference is where the majority of data is stored or where computations are executed. Accomplish all computer calculation as close to the data source as possible and maximize transition of signal to what can be reasonably expected to be used. In most cases, a data ‘pull’ system is much better that a data ‘push’ system. At all cost avoid duplicating unneeded data storage as it results in replicated noise and superfluous copies laying around decreases the efficiency of the entire C2 structure.

5) Human warfighters are the most important and are often the least capable component within our C2 systems. Even in ancient paper-based systems, message recipient may not be correctly understood even when both parties are fluent in the same language. In an IT world, where parties may or may not share a common computer presentation layer, user application incongruities in understanding can quickly arise. The interpretation of the meaning or underlying value of the information has a direct effect on control functions. The least efficient mechanism of inputting data into our macro C2 system is the human on a keyboard. Don’t overwhelm the warfighter with data that would result in his/her degradation. Don’t expect human nature to change. Look to maximize the human warfighter and the organization in which he is part of. Don’t assume the organizational structure of any node is infinite in capability, unlimited in manpower and unchanging. A half a million man force cannot do or effectivity use the C2 structure designed for a two million man force. Decide what decisions, based on what conditions (time, span of control, lethality, etc.) can be off-loaded to other people, organizations or Artificial Intelligence (AI). The choice of ‘not making a decision’ only offloads any results to serendipity.

6) Computers first learned Checkers, then they learned to play Chess and were able to beat the best humans players. The game ‘GO’ is three times more computational complex than Chess and computers have recently beaten the world best ‘GO’ players. The best Chess in the world currently being played is team Chess where humans and computers work together to beat other similar constructed teams. Despite the size of the state space and other complicating factors, these games still don’t compare to the complexity of the military environment (multiple actors, hidden states, synchronous behavior, ill-defined rules, etc.) What beating world champions does imply, is the current and expected vector of technology. In the Information Age the expected vision of the future of C2 is a vision of warfighters and computers working together where the advantage of each can be exploited.

7) Our Joint Capabilities Integration & Development System (JCIDS) documents defining the AOC remain a valid description of the optimal AOC. As we move away from a computer centered approach toward a network centric approach, base on System of Systems engineering constraints we should expect the criteria of success to shift from an
optimal solution towards a minimal satisficing solution. Performance vise Requirements will become the measure of success.

8) The first part of the Information Age was defined by the human machine visual interface. Applications put information on screens to be viewed or manipulated because that is what the available technology could do. We should expect to see a continuing explosion of Natural Language Process (NLP) (think Seri, Alexa or Watson) (and other) computer-based interface technology. The key point is human comprehension of changes is often better accomplished with audio input vise visual inputs. In the first part of the Information Age we use computers as massive ‘pigeon holes’ for information. The operator would place some information into the system and at a later time the same information would be pull out and used or manipulated. As we move toward the future, we should expect routine data handling without human involvement. In complex cases we should expect the computers to consolidate information and offer recommendation to the warfighters. Any currently repeatable human keystroke sequence repeated more than once a day should be able to be automated and offloaded to technology. Human searches of information and manipulation of data should never be more involved than our short-term memory. Excessive keystrokes should be eliminated and multiple human entry of the same data entry is unacceptable. This goal should be applied to system administrators as well as operators.

9) Military computer systems can be broken down into two major branches. Management Information Systems (MIS) an example being Exchange and E-mail and Command, Control, Communications, Computers, and Intelligence (C4I Systems) an example being Theater Battle Management Core System (TBMCS). MIS systems are made up totally of commercial software and in most cases our C4I systems have an underpinning of commercial software (TBMCS is built on an Oracle database). In both cases, major MIS and C4I systems are made up with hundreds to thousands of individual pieces of software that can total millions of lines of code. Very small buys of any C2 computer systems should be expected to remain costly. If a C2 function can be accomplished directly with MIS system, use it, as without a complete analysis the life cycle total cost of ownership should be less as the market base for the application is larger.

10) When everything is working well, the communication infrastructure that binds the AOC into an effective warfighting C2 structure often remains unnoticed by the personnel working in the 5 main divisions of the AOC. In most cases the communicators need and update more information than any single division. It is critical to create a C2 system that does not replace a member of one of the core divisions by requiring one or more additional communicators.

11) In a traditional Operational Plan (OPLAN) Annex J defines command relationships and are built around rank structure and joint doctrine with the output defined in terms of supported and supporting. A canard in the creation of most Annex J is the assumption that communications channels today are as limited as communications were in the later part of the industrial age. In any plan the Annex K will define expected cross domain (network) interactions and information/data flows. In an information age commutation ability/limitation/available infrastructure trumps conceptual organization structure.
Things like what networks that are actually available, Active Directory structure, STATCOM channels and bandwidth drive what information/data can actually flow to and from lower level organizations. A new cross domain solutions can take 6 to 24 months to put into place. Information flow by C2 products can only be created and shared on certain networks. Needed hardware is often limited by availability or even non-existent. Often give time and money these problem communications can be overcome, but in a crisis neither is available. Currently, there are about 3,000 interfaces on the C4I systems at a notional AOC and assuming something close the same number of interfaces on the infrastructure and Management information Systems (MIS) systems, there could be between 6,000 to 8,000 interfaces per network. With AOCs running between 4 and 10 networks the total interface load may be between 24,000 and 80,000 separate technical interfaces at each facility. Most of the problems in systems are at the interfaces and all complex systems have many interfaces. Common interfaces can help to reduce complexity. Additionally, clear interface identification with supporting definition can help reduces system risk. In the end, the overall system architecture drives the selection of interfaces that will be used. It should be expected all interface will NOT be verified during testing as often the data flow across these interfaces are point specific. Processes like creating a Design Structure Matrix (DSM) may help minimize technical risk, but risk and the overall number of interfaces should be expected to remain highly correlated.

What can be technically accomplished with C2 will continue to parallel technology, but the use of C2 will always parallel imagination.

**Extracting Lessons Learned from the Past**

Although, even today, we do not automate the creation of the ATO there is a history of automation systems being used to decrease repetitive entries errors and eliminate the capability of human planners to inject many misrepresentations associated with physical reality (time, space, fuel flow, etc.) Automated building of the Air Tasking Order (ATO) message started with a Disk Operating System program, Frag Works, which ran on a 286 PC in the early 1980s. The program allowed one person (generally a clerk-typist) to fill blank fields in the USMTF message (Today, we would call this message a text or flat file). A group of experts performed all planning (including sortie deconfliction and tanker scheduling) by hand calculation or using another stand-alone computer system. Expert planners would hand the clerk-typist sheets of information to type into message format. The operational data required by expert planners to create a cogitative plan was organized on grease boards or legal paper. The operational data had to be nearly complete before experts could plan individual ATO mission lines to be handwritten on sheets submitted to the clerk-typist.

The next evolutionary leap was the Contingency Theater Automated Planning System (CTAPS). The application in this program that created the ATO message was the Computer Assisted Force Management System (CAFMS), an Oracle Database networked with several UNIX client PCs. All mission planning was still by hand calculation or using another stand-alone computer systems. Information was written on worksheets, passed to a group of clerk-typists (CAFMS technicians), and typed into database fields using Sequel Query Language. CAFMS held both operational and
mission planning data. It allowed Combat Operations to retrieve, sort, and manipulate data as required. Any data that complied with the rules governing that field could be entered. The ATO was printed as a flat file of data from the CAFMS database. All USMTF message fields could be retrieved from this database. The expert planner reviewed the ATO printout to ensure data was entered correctly. CAFMS did not reduce manpower required to organize and coordinate the essential data, but it did substantially decrease time required to type the ATO. Pilot working in Combat Operation had to be taught how to create sequel queries to return text based information/data.

The next generation application, Advanced Planning System (APS), “rode on top” of the legacy CAFMS data structure in the next version of CTAPS. APS was designed to initiate data organization and expedite creation of individual mission lines. APS was a [Smart] database. It incorporated some of the tools used in the standalone computer systems and reduced the need for hand calculations. All required general planning data was entered in APS fields by CAFMS technicians to create an APS data store before the exercise or contingency. The data included base location, aircraft and mission type, standard convention load, fuel burn rate, and other data. Large groups of data such as Airspace individual Air Control Measures or Intel’s Target Nomination List were imported from creating organizations. Hand entry and import of information had to be complete before multiple expert users could begin to type the thousands of mission lines of a large ATO. An APS error message would flag the operator if computer algorithms recognized a conflict. For example, the error message: “Unflyable Mission” might prompt the user to review the planned line and find it to be short 100 lbs. of fuel. For aircraft flying 8 hours 100 lbs short of fuel, an operator could determine the “problem” insignificant, and override the computer. APS was adept at pairing fighters and tankers and determining appropriate fuel for strike missions. It did straight line planning for each mission line created. Air mobility command elements did not use APS to plan theater and strategic airlift. In the earliest version of APS, certain fields could not be overwritten and not all fields in the USMTF message could be automatically filled in creating the ATO message. When planners completed entry into APS, the data was transferred back to the legacy CAFMS database. The ATO message went back to the database where airlift missions, Special Instructions (SPINS) and information needed to fill in other fields was added. The final ATO message produced with APS was still a USMTF flat file.

The APS application successfully represented data and constrained use of resources with detailed data models that combined a relational database with a volatile knowledge base and implemented business rules in algorithms. Some of its behavior models were pure physics (rate/time/distance) that prevented objects from attempting to occupy the same space at the same time.

The sizeable investment in APS and the success it achieved led to creation of TBMCS Theater Air Planner (TAP) as it was based on the same design philosophy. TAP inherited much of its computer code and many input screens from APS. It incrementally “fixed” most user problems associated with APS; updated the year group of the USMTF message created; and implemented time and ATO production manpower reduction protocols. Pilots no longer had to be taught how to create and execute Sequel Queries they only had to be taught how to use mouse and keyboard to search for needed information using TBMCS web enabled Execution Status and Monitoring Tool (ESTAT) and Force Status and Monitoring Tool (FSTAT).
Supplemental tools beyond formal Systems of Record (SOR) can improve overall user experience and increase effectiveness. The Air Force made operational planners’ lives a little better by introducing Master Air Attack Plan Tool Kit (MAAPTK), a modernized planning tool used in the Air Operations Center (AOC) to develop missions for inclusion into an Air Tasking Order (ATO). MAAPTK allows planning thru “drag and drop” technology with an intuitive visual interface. Input and search is more “mouse” than keyboard based GUI interface and instead of primary test manipulation. Missions built by the planners using MAAPTK still must be transferred to TBMCS for the operators to execute using ESTAT and plethora of support applications.

The history of ATO production is very similar to the history of other major C2 applications. MDC2 derives both unsolved problems set and clearly define goals from this history. If C2 application design continues to use mouse and keyboard as primary input devices, information into and extracted from systems will remain as limited as it was in the early 2000’s. To advance global C2 capability MDC2 applications must augment keyboard and mouse technology with voice and audio or when appropriate totally replace keyboard and mouse with voice/audio. There is already a huge effort underway to improve voice-based interfaces, and it’s rooted in the idea that digital devices like Siri and Amazon Echo will take on increasingly prominent roles in people’s lives.

An Executable vision of MDC2

The inexorable progress of technological innovation creates possibilities as it destroys established processes and augments current knowledge. After Action Reports and lessons learned are not written where you can easily extract negatives (hindering) impacts of technology. Problems identified in After-Action Reports often are not smoothly morphed to solutions. The industrial-military complex talks a good game but nothing much moves us away from an industrial based military toward a more information-based organization. Funding (color and type of money), policy, security, Program Elements (PE’s), and may other fragmented functions inhibit progress. Technical (physical) reality drives what can actual happen and stove pipes systems correlate directly to funding. Physical reality associated with complexity is increasing. For most weapon system their boundaries are physical (tank, ship, airplane, etc.) with a few data exchanges crossing the boundaries. As mentioned, the AOC or any C2 node could has 5 to 10 or more IP based networks with high security guards (HAGs) crossing the networks, plus a few non IP networks (Radio, phones, video, etc.) and no physical boundary that define a crossing function for all of the information flow. Some great ideas that had the full support of powerful leaders have not ended up making it to the field. MDC2 as a future Command and Control (C2) construct will remain sociotechnical entities where individual human warfighters and their organizations must sort through and deal with an explosion of available data, coupled with the complexity and timescales required for decisions, planning and execution. Computers within C2 have long surpassed the reality expressed in Weise 5 vision paper published in 1991. In most cases each and every C2 warfighter will have multiple computers with multiple screens connected to several different networks at whatever seat he chooses to set in. All of this

computation power at his fingertips was not built to implement organizational workload reduction. In many cases the expenditure of huge capital resources has only resulted in some very pretty, very expensive electronic place holders where data is either directly manipulated by the warfighter, view or stored for later use. There is little fundamental research supporting the belief that sharing (or having access to) all available data actually improves the speed or quality of decisions. MDC2 has the ability to improve overall SA and move all engaged organization towards “Edge” C2 maximizing the effort of the whole force by moving towards quantitative decision making. It is a false assumption to assume organization having access to all available data (data lake/data pond) will correctly extract their needed information and the information they need will be there by default. If critical data are fish swimming in common total data pool, does the density, size (importance) and ease to catch the type of fish you may desperately need, change in proportion to the size of the pool? In other words recent history has validated we are truly entering Maykish’s Stage 6 of Air Power\(^6\) but current MDC2 design language is far below the standard set by Boyd\(^7\) for Stage 5. By definition a priori information and a posteriori information can never be completely overlapping sets. Theoretically the closest the two independent sets of data/information can ever reach is limited by communication theory as described by Shannon\(^8\), Ashby\(^9\), Beer\(^10\) and others. Besides imaging away or writing around serious technical issues MDC2 reinforces the use of large-scale Systems of Record and indirectly supports the current acquisition process. Banging our collective heads against the government acquisition wall and shouting for some new optimal solution being delivered by the current macro process is only hoping for different results from the same type of inputs (conceptual outcomes) that have so often have been provided; I would posit it as a non-winning strategy. In the paper “US Army Information Technology Management” by Casazza, Hendrix, Lederle and Rouge\(^11\) (2012), the authors argue convincingly that the very structure of a US military organization inhibits adaption of new technologies:

[T]he U.S. Army remains the most technologically sophisticated military force in the world, extraordinarily efficient and effective at its mission to defend and protect the peace and security of the United States, its national interests, and objectives. However, when attempting to integrate the rapid advancements made in information technology, it has invested considerable resources with little success. …

It is therefore unsurprising that in our case studies, we found more success in the private sector. However there are factors that apply generally to any attempt at broad organizational change via technology, which can aid in adapting to the case of the Army.

I have to agree with Steve Casazza, pursuing a standalone technical optimization (no matter how wonderful the vision) of a military only the data infrastructure has little hope of achieving a global optimization of C2 across the totality of any engaged US military force. It is the “wetware” (humans and their organizations) not the hardware or software that must be optimized.

Humans are the glue that work across otherwise stove-piped organization. To restate - Conway's law state: "organizations which design systems ... are constrained to produce designs which are copies of the communication structures of these organizations." Currently large-scale Command and Control (C2) systems represent military organization doctrinal “stovepipes” by policy and user functional paralleling the scope, capabilities and desires of their funding organization resulting in their technology being exceptionally “brittle” in the face of change. Designers of these individual silo systems must explicitly define, often in excruciating detail, all actions and behaviors of their systems needed to operate as designed, often to meet unique requirements only defined in their individual contracts. For openly complex and dynamic (sometimes approaching chaotic) facilities like the AOC, which are made up of tens to hundreds to thousands of pieces of individual hardware and software “systems”, it becomes nearly impossible to technically specify what macro level systems actions and behaviors will result for all possible micro interactions, conditions and situations. Because there is a huge, maybe infinite, numbers of ways to internally and externally configure all these different “systems” it is foolish to expect any final integrator/developer/designer/contractor/company to develop suitable responses for all relevant /expected eventualities. Individual standalone systems are often developed in separate contractor facilities where their designers only have a perception the actual operational milieu or of the actions and behaviors that will occur in the final domain. As a consequence, we have towering applications that can only preform, relatively well, under a small and finite set of conditions that have been specifically anticipated and represented. With DOD 5000 Acquisition policy and regulations expected to maintain its current vector and with the results of 3 historical attempts at major AOC change behind us, it is not hard to surmise the expected outcome of MDC2 if there is not a measurable improvement in global C2.

Does the way forward only result in begging to be placed in the cooler parts of our ever-increasing complexity hell? I don’t think so - if we push forward both the science and art of engineering maximizing the human warfighting organizations.

The following assumptions about the future have been made to posit an executable MDC2 solution:

1. Military “need to know” will drive what information is releasable to whom and when it is released.
2. Major military organizations relationships will continue to be described in terms of “Supported” and “Supporting”.
3. The flows of funding in terms of “color of money” and associated Program Element (PE) will vary no more the 5% of what is currently planned.
4. The process of military strategy creation and the logistics execution of that strategy will remain much as it is today.
In 1966 Joseph Weizenbaum created a program called ELIZA that achieved the illusion of intelligence using prewritten scripts creating one of the first chatbot/verbal activated computer assistants. The first decade of the 21st century was an exciting time for chatbots as they began becoming truly intelligent. While previous chatbots had relied on pattern recognition, 21st-century chatbots exercised machine learning and evolutionary algorithms, enabling them to adapt and “learn” based on their interactions with humans. In 2006 IBM created Watson. Watson’s high level of linguistic intelligence came from its ability to run hundreds of language analysis algorithms simultaneously. On top of this conversational intelligence, Watson had access to enormous databases of information. Watson could quickly access 200 million pages of data, making it the ideal question-answering machine (or, in the case of Jeopardy, the ideal question-generating machine). Obviously, a system that can rapidly retrieve information based on conversational input can also provide the foundation for creating powerful virtual assistants. Now, IBM Watson serves as the “brains” for many chatbots across all industries and sectors. The first half of this decade witnessed the rise of virtual personal assistants: Siri (2010), Google Now (2012), Alexa (2015), Cortana (2015), and Google Assistant (2016). Using natural language processing, these assistants connect to web services to answer questions and fulfill user requests. There is no technical reason to provide warfighters with only a mouse and keyboard and months of training for them to accomplish a difficult tree search of multiple systems. It should be expected much first order knowledge work will be offload to technology within the next few years, as the trends are already developing.

The bots that enable verbal/audio interface are executing semantic technologies. Semantic technology encodes meanings separately from data and other content files, to include being separately from individual application code. This enables computers as well as people to understand, share, reason and work with together. In 1950 Alan Turing wrote “Computing Machinery and Intelligence” formulating the Turing Test. To pass a Turing Test a computer and a human must be indistinguishable from the prospective of a human evaluator. Semantic technologies are the underpinning that will enable all computers to pass a Turing test. A little over 100 years ago tactical units engaged in the “War to End all Wars” were sometimes communicating with notes strapped to legs of pigeons. Semantic technology today will not pass a Turing test for every situation encountered. In something far less than 100 years it will. Semantic technology is increasing effectiveness, and efficiency of AI, by making AI systems more perceptive, intelligent and collaborative Semantic technology consists of a variety of concepts that have emerged from AI such as natural language processing, speech recognition and planning, etc. The collaboration of semantic technology and AI is providing experts with new techniques for building intelligent systems or agents that can allow users to find answers to their queries more precisely. A Goggle search will display returned documents that may contain information requested, but if you ask “Alexa” the same search the exact answer will be provided. Semantic technology helps in extracting meaning from unstructured content, through the juxtaposition of interoperability standards like HTTP, XML, and RDP. This helps in reducing uncertainties in cognitive computing. Cognitive computing plays an important role in extracting useful information from unstructured data with the help of cognitive techniques such as pattern recognition and natural-language processing. Semantic technology helps cognitive computing in achieving this role. I recently finished reading a DARPA sponsored paper (DARPA W911NF-15-C-0246) titled "Event Representations for Automated Story Generation with Deep Neural
"Nets" written by several members of the School of Interactive Computing, Georgia Institute of Technology from Atlanta Georgia. The paper is undated, but appears to have been written after 2012. Their experiment was to use a recurrent neural network (RNN) to accomplish automated story generation. Most of what we deal with in the AOC are either short, longer or very long "text strings" that could be automatically/initially created by any "story generation" type RNN. Semantic technology pushes cognitive computing in translating and connecting data to create accessible frameworks. The collaboration of semantic technology and cognitive computing facilitates the development of heterogeneous ecosystems that can allow content everywhere to be available, readable, and comprehensible to both human and automated consumers.

Precis

More data, more systems, greater complexity, does not by default change C2. It may change the pattern of interaction and the distribution of information that can be measure to determine if the overall C2 moved towards Edge or away from Edge. If MDC2 just ends up moving just more “noise” through the physical infrastructure to be shared by all, we are not improving C2. Humans will find ways to trash what they think of as noise. Napoleon created the A-1 thru A-6 structure to become better organized. The questions everyone is working through is how to move from an industrial organization dealing with monstrous gob of data to a warfighting organization that can best understand reality and exploits that understanding better that anyone else in an information age.

Artificial Intelligence (AI) is a set of ever growing of mathematical manipulations that concern choice. Almost everyone recognizes and has a basic understanding of the term “cloud”. If you are in any discussions about clouds you soon move well pass the general term “cloud” and start discussions about types of clouds or artistic expression in clouds or some other technical details about clouds. AI as a term express the same level of understanding of machine selection of choice as the term general “cloud” express about various fluff white objects in the sky. There are many different types of mathematical operations that deal with AI (choice) and each should be used where appropriate to gain mastery over the argument/arguments under question. Latching on to one AI method (algorithm) and attempting to extend that method to resolve any and all AI (choice) issues has been validated (in terms of both resource expenditure and success) as a highly inappropriate strategy. It should be expected that AI within C2 will be express in many different ways, based on the issue being addressed.

When hand-held circular saws were first introduced to the construction industry the average time between overalls (TBO) was just 4 hours. The cost to manufacture the first 7” blade was $1000.00 in 1924 dollars. The saws could not be built fast enough to satisfy the market as there is an extreme difference in the productivity between a job site where everyone is using just hand tools and a site with just one electric skill saw. Fifty years ago Doug Engelbart (computer scientist) demonstrated the computer mouse, graphical user interface (GUI), hypertext, video conferencing and more. Boyd’s insight into how these systems can be used to support Air Power produce the AOC today. Half a century later military C2 is still relying on the computer interactions Engelbart demonstrated and Boyd evangelized. Imagine the next operation “BOLO” consisting of a flight of maned fighters, a swarm of AI entities, or a mixed flight of humans and
AI flown machines, or remote humans and AI, all being supported real time by a group of cyber warriors disrupting the logistical chains, ground communications and situational understanding the adversary. Imagine what AI/ML can do: could it given national level military objectives use AI (an RNN) to build an initial strategy set of Operational Objectives (OOs), Tactical Objectives (TOs), Tactical tasks (TTs), and their Measures of Performance (MOPs) and Measures of Effectiveness (MOE’s) along with their associated Measures and Indicators (M&Is) associated. Could AI be used to create other "text string" document like an initial CONOPS/CONEMPs, AODs, OPLANs, etc.

TBMCS (the current system being used) has the ability to create an automatic ATO based on the planning factors that are loaded, but the results are have yet produce a flyable product that an AOC Commander would release. Unfortunately, the ATO process since WWI and the beginning of Air Power has been a qualitative process driven by military prerogative. With the advent of information age and employing Boyd’s philosophy the ATO process was supplement with technology that became little more than complex electronic niche where the data is store - removed and manipulate by humans -and replaced. In the late ’90/early 2000 there was a serious attempt to move past Boyd and optimize/automate the ATO with a DARPA program call Jaguar. The program was finally canceled as the data veracity remained low to very low and the users rejected the output. In 2018 DARPA had a vendor that was offering an application name SHARP that gave the users a less intrusive ATO production tool that allowed the user to select between various options. The SHARP tool was down selected and chosen not to move forward in development. Optimizing is always a mathematical "hill climbing" event and the user community has not expressed a joint consensus on what needs to be optimized (quantitatively decided) to achieve a military advantage. Information warfare moves decision methodology from qualitative to quantitative which, used correctly, can be demonstrated to be superior for a large subset of problems. If you have seen the movie "Moneyball" starring Brad Pitt it shows the organization biases and the success and failures of changing decision styles from qualitative to quantitative. Various mathematical techniques can be highly effectively when used to evaluate an appropriate problem/issues/condition and can become a waste of time and resources if a method is selected and then attempted to be use by "backing into" a problem/solution.

In any battle there is little time for prospective. In an information age peer to peer conflict there maybe scant time available post event for the loser to accomplish any analysis. The military community or our adversaries will determine what processes/products are best produced with human’s in-the-loop, on/monitoring-the-loop or completely off-the-loop. Let’s not play the role of the French at Agincourt and bask in our assumed conceptual superiority the night before the battle. In the next information war fight, there will be no inherent “right” to military victory. Technological risk and military risk are not equivalent, although they may be overlapping subsets in certain domains. Moving to micro services or decreasing the time to receive an Authorization To Operate or Approval To Connect (ATO/ATC) for some software/system, the use of cloud technology or some cross domain chat is not the same risk as a four ship “arming hot” and going “Downtown”. The A3/A5 communities and their supporting acquisition and A6 communities are expected to have grinding organizational interactions to insure senior leaders can balance overall risk. There is a long and well document history of technologist solving "their" nodal technical problems and inadvertently moving overall C2 towards a less effect construct. Moving MDC2 towards “Edge” C2 increases self-synchronization and the gestalt
ability of the whole. The sun is quickly rising on the next Information war battle and there is only time enough to work very hard and effectively to actually implement technology/process/and solutions that can produce the conceptual outcomes so well actuated by the MDC2 program.
Today, the Air and Space Operations Center (AOC2) Weapon System, AN/USQ-163 Falconer, military C2 data center node is the senior element of the Theater Air Control System on the battlefield. The primary function of the divisions of the AOC is to produce and execute an Air Tasking Order (ATO) and associated documents like the Airspace Control Order (ACO). The Air Force fielded five permanent Falconers worldwide to meet continuing air power challenges. In any operation involving air power, a single commander is designated the responsible member for all air power forces assigned and attached. In a theater-size military campaign, as many as 2500 people inside the Combined AOC (CAOC) move massive amounts of information across multiple communication networks of various security levels. The Falconer is the core production hub of the much larger CAOC facility/compound. The entire CAOC provides the Commander the capability to direct the activities of assigned, supporting, or attached forces and monitor the actions of both enemy and friendly forces. Walking into any of the five worldwide CAOCs for the first time is an extraordinary experience. It is just what you expect of the nerve center of the most powerful Air Force on earth. Huge projection screens show the exact location of every military aircraft flying over the theater of operations; CNN, Fox, and other news organizations; and other situation displays. Rows of professional warriors operate computer screens and banks of telephones communicating worldwide while absorbing vast amounts of information from organizations across the planet. The Combined Force Air Component Commander (CFACC) sits in a room with his key staff. Video and data screens show live feeds from various sensors over the battlefield. Chat rooms on computer screens exchange information across all security levels.

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1 Kometer Michael W., Lt Col, USAF, “Command in Air War: Centralized vs. Decentralized Control of Combat Airpower” Ph.D. Dissertation at the Massachusetts Institute of Technology May 2005