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**FIGHTERS INTEGRATING INTO MULTI-DOMAIN OPERATIONS:
THE ANTI-ACCESS, AREA-DENIAL ENVIRONMENT**

Major Brian Cox

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JCSP 46	PCEMI 46
Solo Flight	**Solo Flight**
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SOLO FLIGHT

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INTRODUCTION

The challenges of fighting in an Anti-Access Area Denial (A2/AD) environment and the introduction of 5th Generation Fighters into the Battlespace has offered an unique chance for the Airforces' of the world to integrate their special capabilities into Multi Domain Operations (MDO). MDO is the integration of all domains into one synchronized force where windows of superiority can be achieved. It will be the 5th Generation Fighter's ability to share a combined Air and Surface picture across the battlespace, unlike any previous fighter aircraft before, that will promulgate Cross Domain action and coagulate the future of MDO.

Those operational concepts that have existed with 4th Generation fighters for the last 30 years will be ineffective against an Aerial Area Denial environment. This Aerial Area Denial environment will force the aviators, especially fighter pilots, to rethink their tactics, techniques, and procedures and develop new operational concepts to incorporate the legacy 4th Generation Fighters with 5th Generation fighters. By channelizing the advances in technology of 5th Gen Fighters and improving the Aviators' Airmindedness,[1] the Air Domain will contribute significantly to MDO.

The use of 5th Generation Fighters, such as the Lockheed Martin F-35 Lightning II with 8 million lines of code dedicated to sensor fusion[2], will improve the odds of success of MDO being executed by the Airforces. But those advanced capabilities will

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[1] United States Air Force, "Basic Doctrine, Volume 1", Air Force Doctrine, 27 Feb 2015: *Airmindedness is the perspective of Airmen; it reflects a unique appreciation of airpower's potential, as well as the threats and survival imperatives unique to Airmen*

[2] Lockheed Martin, "A Digital Jet for the Modern Battlespace", F-35 Lighting II Software Website, https://www.f35.com/about/life-cycle/software.

only be effective if a network of information is instantaneously shared between environmental elements. In comes the "Combat Cloud" to synchronize Air, Sea, Land, Space and Cyber effects with corresponding 5th Generation capabilities. A mass network that integrates complementary capabilities into a single, combined 'weapons system' to conduct disaggregated, distributed operations over a fluid operational area.[3] The Air War and its contribution to MDO will see an exponential growth with respect to the technological requirements to integrate information across the battlespace.

One of the conditions to coordinate this new paradigm of shared information will arguably switch the Air Domain tenants' of Command and Control (C2) from Centralized Control, Decentralize Execution to a Unified Command, Distributed Control, Decentralize Execution.[4] The current force will transition to a new way of C2 through a new generation of Aviators, Sailors and Soldiers that will be well-schooled and capable of understanding network synchronization.

The thesis of this paper will contemplate how the Royal Canadian Air Force (RCAF) will integrate into Multi Domain Operations with Combat Cloud technology while utilizing the advanced war fighting capabilities of a 5th Generation Aircraft to have an 'operational advantage'[5] in the A2/AD environment. This paper will answer two specific questions: How will an RCAF Advanced Fighter provide warfighting capabilities in an Aerial Area Denial (AD) environment through Multi-Domain Operations; and what

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[3] Deptula, David (Lt Gen), "Intelligence, Surveillance and Reconnaissance in the Information Age", Leading Edge Airpower in Theory & Practice, 9 Jun 2015, https://leadingedgeairpower.com/2015/06/09/intelligence-surveillance-and-reconnaissance-in-the-information-age/.

[4] Airforce TV "Demystifying Multi-Domain Command and Control, 2019 Air, Space & Cyber Conference" 20 Sep 2019. https://www.youtube.com/watch?v=8zgZWiomzas

[5] Pelletier, Alain (MGen RCAF), "Future Fighter Industry Day Statements", Public Service and Procurement Canada, Chief of Future Fighter Capability Project, 13 Nov 2019.

technological advances and concepts will be required by the Canadian Armed Forces (CAF) in order to benefit from an 5th Generation Fighter in the MDO concept? In explaining the concepts, this paper will use the four T's (Task, Target, Threat, Tactics) as a method of writing. This is the same format and thinking that a fighter pilot may use to analysis the upcoming mission and derive a plan.

TASK- FIGHT A2/AD THROUGH MDO

Anti-Access Area Denial (A2/AD)

The A2/AD environment is an attempt to deny an adversary's freedom of movement on the battlefield. This can be divided into the two parts:

> Anti-access – the inhibition of enemy military movement into an area of operations to utilizes attack aircraft, warships, and specialized ballistic and cruise missiles designed to strike key targets; [6] and

> Area denial - is the denial of enemy freedom of action in areas under friendly control which employs more defensive means such as air and sea defense systems.[7]

In the case of the Air Domain, this can be further addressed as Aerial Area Denial (AAD) operations. AAD includes the coordinated operations by an enemy's air forces and integrated air defense (IADS) forces to maintain a degree of air parity or superiority over their territory and forces.[8] For the most cases, AAD systems will be a combination of networked Surface-to-Air Missiles (SAM) and fighter aircraft. It will be this AAD construct where the core capability, Control of the Air will be contested.

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[6] Krepinevich, Andrew; Watts, Barry; Work, Robert, "Meeting the Anti-Access and Area-Denial Challenge", Center for Strategic and Budgetary Assessments, 2003, 95.

[7] *Ibid.,* 95.

[8] *Ibid.,* 95.

Therefore a joint approach to A2/AD capabilities is crucial to success in the future wars against a determined enemy.[9]

Multi-Domain Operations

Multi-Domain Operations (MDO) is this next joint approach concept. MDO is using all Domains; Air, Land, Sea, Space and Cyber, and sometimes Information[10] in a synchronized action against the enemy. By creating temporary windows of superiority, MDO allows joint force freedom of action.[11] This is a change from Air-Land Battle concept, which was focused on two domains and did not envision the multiple domains working in close coordination to achieve the desired effects. In addition, the Services must fully integrate space and cyber capabilities into warfighting systems.[12] Space and Cyber systems allow us to mass and concentrate fires while synchronizing widely dispersed and disaggregated forces.[13]

Within MDO, one of the main concepts is target sharing. Target sharing or cross domain action means selecting the domain as required to engage the target. This does not mean that is the domain that is providing the targeting information such as coordinates or identification. With MDO, a single target could be engaged by two or more domains at the same time while synchronizing their effects to achieve the desired outcomes.

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[9] *Ibid.,* 95.

[10] Canadian Armed Forces, "Pan-Domain Force Employment Concept Prevailing in an Uncertain World", Government of Canada, 2020, 49-50.

[11] OEC G&V Channel, "Multi Domain Battle Short Version", 9 Apr 2018, https://www.youtube.com/watch?v=RwYHSn_vAhQ&t=153s

[12] Igl, Chadwick D., Candy S. Smith, Daniel Fowler, and William Angermann. "568 Balls in the Air: Planning for the Loss of Space Capabilities." *Joint Force Quarterly* 90 (3rd Quarter 2018):, 25.

[13] Thompson, David "D. T.", Gregory J. Gagnon, and Christopher W. McLeod. "Space as a War-Fighting Domain." Air & Space Power Journal 32, no. 2 (Summer 2018):, 4.

MDO with Air Domain Fighters

The Air Domain will have to leave the traditional approach that has existed since the Vietnam Air War period and adopt new ways to fight. The Airforce will have to evolve from the massing fighters, bombers, and supporting aircraft that have formed major strike packages and formulate into a Multi-Domain force that simultaneously executes cross domain effects. Without change, the Air Domain would not be able to attack a particular target area without a major effort or significant losses. In order for the Air Domain to join MDO, it will need to utilize the advanced technologies from 5th Generation Fighters.

The key feature that describes a 5th Generation Fighter is stealth/low observability that allows for freedom of movement in a contested Air Environment. While the contested environment is associated with IADS and Air-Air Fighters, it is not the only threats that the Air Domain needs to consider when contributing to MDO. The Air Domain needs to also support Land and Surface Operations by detecting threats to Ships and Land Force such as Artillery or Anti-Ship Cruise Missiles. As mentioned by Air Force's Global Strike Task Force (GSTF), the Navy will have no realistic means of attacking these defenses with manned aircraft until the F-35 Joint Strike Fighter enters service.[14]

> United States Air Force (USAF) has aggressively pursued innovation in two broad areas. The first, and most pressing, is a shift to a "Multi-Domain Operations (MDO)" mindset. The USAF Chief of Staff, General David Goldfein (2018) says this transformation is vital to prepare for future warfare.[15]

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[14] Krepinevich, Andrew; Watts, Barry; Work, Robert, "Meeting the Anti-Access …, 95.

[15] Flack, Nathaniel, "Self-Directed Learning Tools in USAF Multi-Domain Operations Education" Department of Electrical and Computer Engineering, Air Force Institute of Technology, Dayton, USA, 752.

While the F-22 is primarily an Air Superiority Fighter, it also is capable of identification and location of Radio Frequency (RF) Emissions and it can use Semi-Active Radar (SAR) modes to identify ground targets. Other 5th Generation Fighters like the Joint Strike Fighter (JSF) F-35 Lightning II go beyond the F-22's capabilities and can additionally sense in the Electro Optical and Infrared Spectrum. But with MDO, these advanced sensor capabilities need to be distributed to other domains for target sharing. The JSF F-35 has the ability to absorb and disseminate information better than any aircraft in the history of aviation.[16] It is this ability that will make the Air Domain one the critical elements to integrating into MDO.

As the introduction of 5th Generation Fighters transitions into current operations, there will be the continues use of 4th Generation aircraft like the RCAF's CF-18 Hornet to be employed. For MDO and 4th Generation fighters to contribute or operate with MDO there will need to be a network to share with all domains. Currently, 4th Generation and 5th Generation Fighter collaborate on an Airborne Data link called Link-16. Link-16 is a target and friendly aircraft secure data link that can be fused with Naval and Land Domains, but has a limited bandwidth when it comes to the requirements for MDO. Thus the need for an advanced network with the goal of allowing a fully connected network for all of the domains to operate within. The will be discussed later as the 'Combat Cloud'.

TARGET-AIR BATTLE MANAGEMENT AND CONTROL

5TH Gen Fighters Edge Formations

With the implementation of 5th Generation Fighters, like the F-35, the traditional control that was developed for 4th Generation fighters will have to change to meet the

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[16] Hamilton, Tucker (Retire Lt Col), "F-35 Lightning II", Fighter Pilot Podcast, Episode 78, Interview with former F-35 Test Pilot, 13 Apr 2020.

dynamic aspects of the AAD airspace. There will be a greater need for the allocation of

decision rights and the diminishing of control from the Air Operation Centers (AOC) to

5th Gen Fighter pilots.[17] With the use of an advanced data-link (later discussed as

'Combat Cloud') and a change to agile C2 concepts such as 'Power to the Edge',[18] 5th

Gen Fighters will be empowered to act autonomously all while still sharing their

information with command and other domains.

> *Over the past decades of intense counterinsurgency operations, aircraft have been coupled with stubborn networks and high-level command visibility of combat situations, have muted some Airmen's instincts for independent operation.*[19]

With a 'Power to the Edge' C2 concept, it is anticipated that Fighters will operate

in large spread formations to extend their sensor coverage for self-targeting scenarios.

This will enhance the combined Air and Surface picture through sensor triangulation, and

it will single out the threats on the battlespace. These formations, composing of three to

nine 5th Gen Fighters, will replace the large strike packages. They would be capable of

executing what normally would require 30-50 multi-role fighters and additional

supporting combat aircraft.

One of the outcomes of these 5th Gen formations is the requirement to act in a

team mindset with a set of rehearsed gameplays. These gameplays would now be

coordinated/called under the leadership role of a single Fighter pilot that would be trained

to operate as the quarterback[20]. The Wingman in the formation would have additional

freedom to act and prosecute targets within the gameplays while respecting the rules of

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[17] Nakul, Nayyar (Maj RCAF), "Fifth Generation Command and Control", Service Paper JCSP 46, 25 Oct 2019, 9.

[18] Alberts, David S., and Richard E. Hayes. "Power to the Edge: Command and Control in the Information Age." *Command and Control Research Publication Series (2005),*6

[19] Hostage III, Gilmary Michael and Larry R. Broadwell, Jr., "Resilient Command and Control: The Need for Distributed Control", JFQ 74, 3rd Quarter,201.

[20] Newdick, Thomas, "Lightning in the Sandbox", Air Forces Monthly, 375, (June 2019), 15.

engagement (ROE). This agility to have Wingman executing against threats

simultaneously is the basis of the 'Power to the Edge' [21] concept for 5th Generation
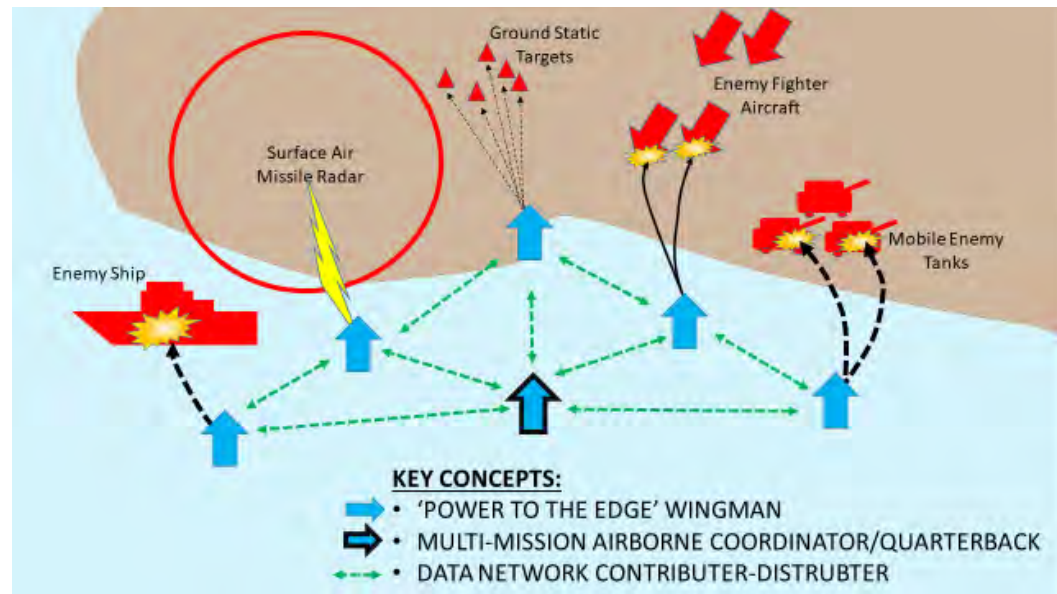
Fighters as seen in Figure 1.

Figure 1: 'Power to Edge-5th Gen Fighter Formation'

There are three key concepts that can be explained that will reinforce the 'Power

to the Edge' for 5th Generation Fighters. First, each Fighter Aircraft will act as a Data

Network Contributor Distributer (DNCD) and act as a node in the formation to which is a

capable of relaying fused sensor information to a Battle Management or AOC. Second, is

that some Fighter Pilots in the formation will become Multi-Mission Airborne

Coordinators (MMAC) or quarterbacks[22], replacing the role that was traditionally

executed by Ground-Controlled Interception (GCI) or Air Weapons Controllers (AWC).

Third, is the concept that every Wingman within the formation will make their own

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[21] Alberts, David S., and Richard E. Hayes. "Power to the Edge: Command and Control in the Information Age." *Command and Control Research Publication Series (2005),6.*
[22] Newdick, Thomas, "Lightning in the Sandbox", Air Forces Monthly, 375, (June 2019), 15.

airborne decisions with respect to identification, targeting, and engagement, enabling faster decision making at the tactical edge. [23]

Air Battle Management

One of the operational changes to the Air Domain with the implementation of 5th Generation Fighters is the re-assignment for the Airborne Warning and Control System (AWACS) aircraft. The AWACS, is currently the main airborne sensor on the battlespace would be redundant because of the sensor and network capabilities of the 5th Gen F-35. Instead, the AWACS would be re-assigned from an Airborne C2 platform to an Air Battle Management (ABM) role. The sensor information from a formation of 5th Generation Fighters could be shared through satellites. This concept of converting to an ABM team and potential removing the AWACS is not only discussion of this paper, but it is also being discussed in the United States Air Force as they look at the contested environment and how they are going to fight.[24]
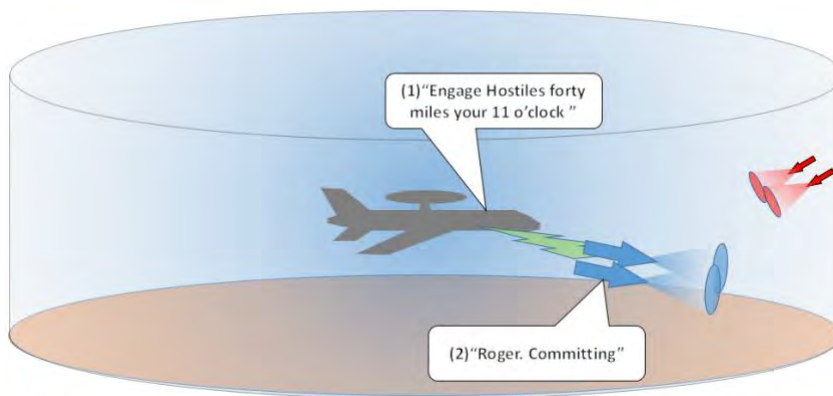
Figure 2: Traditional Airborne Control

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[23] Nakul, Nayyar (Maj RCAF), "Fifth Generation Command … 9.
[24] Everstine, Brian W, "The F-22 and the F-35 Are Struggling to Talk to Each Other ... And to the Rest of USAF" *Air Force Magazine,* (March 2018), 38.

> *"How much information you[F-35] have about the battlefield. I [Pilot F-35] don't need AWACS anymore telling me a lot information. I [F-35] have more information than they [AWACS] do"*[25]

The difference in Air Operations with the AWACS being reassigned to the ABM role is explained in more detail. For instance, the traditional AWACS or GCI controllers' direct fighter aircraft through vectors and provide engagement authorities, as seen in Figure 2. This is because the AWACS had superior radar and identification capabilities over most 4th Generation Fighters. This type of Airborne control would be outpaced with the advanced sensor capabilities in the 5th Generation Fighters, like the F-35 and F-22. The other significant change is the ability for the F-35 to provide a combined Air and Surface picture. With a formation of 5th Gen fighter aircraft, a bubble or volume of the battlespace can be transmitted to support the global or regional picture, as in Figure 3. It would eliminate the need for AWACS aircraft as a control platform.
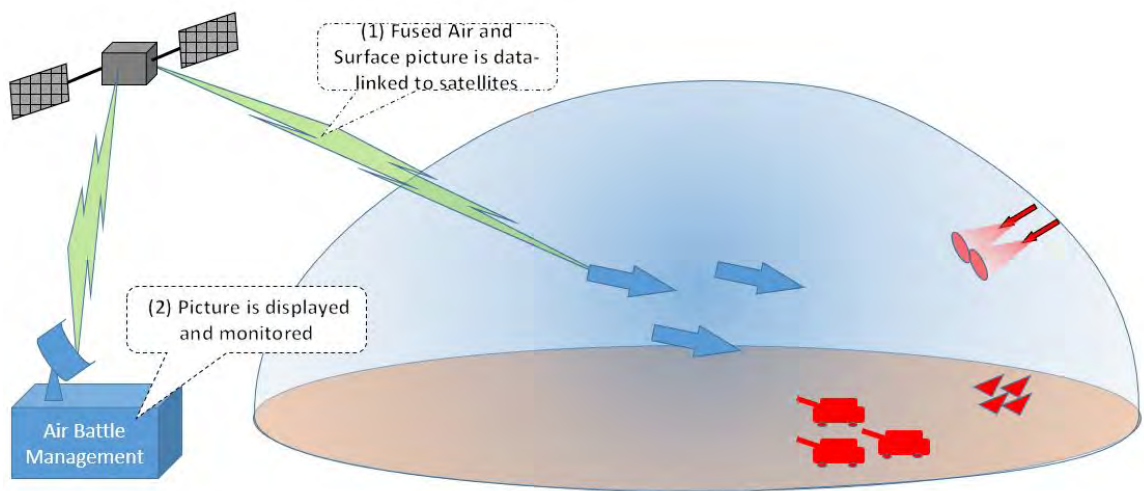

Figure 3: 5th Gen Fighter and Air Battle Management

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[25] Hamilton, Tucker (Retire Lt Col), "F-35 Lightning II", Fighter Pilot Podcast, Episode 78, Interview with former F-35 Test Pilot, 13 Apr 2020.

It's understandable that with the reallocation of AWACS aircraft there would be a lack of persistence over the battlespace. The fuel normally used by the AWACS can be translated to additional fighter aircraft and/or other Air-Air Refueling (AAR) aircraft. Not only can AAR aircraft extend the range and persistence of the Fighters, but it can be used as a relay platform or as another information sharing node (Further discussion in 'Combat Cloud').

THREAT – DEGRADED C2

Contested Air Operation Networks

In the A2/AD environment, the resilience of our networks, datalinks, and communications will almost certainly be contested.[26] The Air Force's Air Superiority 2030 Flight Plan has outlined current and future threats and is conducting an Advanced Battle Management System analysis to include the next generation of networks and radio designed for operations in highly contested environments.[27] To assume that space capabilities, including ground systems, will be available and dependable in a conflict is inherently dangerous.[28] The ability to communicate and transmit data from 5th Generation Fighters through Space to an ground based ABM will jeopardize the C2 backbone.

The one domain that Fighter Aircraft will need to rely on is the Space Domain. Fighter pilots must understand what are the consequences with a loss of space effects.[29] Fighter Aircraft may need to work independently utilizing tactics and procedures that do not rely on space systems.[30] The loss of the common operating picture could be

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[26] Hostage III, Gilmary Michael and Larry R. Broadwell, Jr., "Resilient …201.
[27] Everstine, Brian W, "The F-22 and the F-35 Are Struggling to Talk to Each Other ... 38.
[28] Igl, Chadwick D., Candy S. Smith, Daniel Fowler, and William Angermann. "568 Balls …25.
[29] *Ibid.,* 26.
[30] *Ibid.,* 27.

unreliable for situational awareness because of GPS timing signals would be unavailable.[31] In order to conduct MDO, the need for communicating and maintaining a shared targeting network in a contested environment would be provided by the 'Combat Cloud'(redundancy discussed in 'Combat Cloud' section).

Multi-Domain Command and Control

To formulate all the domains into one command and control would require the development of a Multi-Domain Command and Control (MDC2) concept. With the decrease in communication capability in A2/AD this will force a return to the true concept of decentralized execution, which will require Mission Command be given to military leaders at all levels.[32] This leads to a shift from the Airforces' tenant of Centralized Control and Decentralized Execution to Unified Command, Distributed Control, Decentralize Execution.[33] This means that MDO forces would bring together all domains under a single command that distributes the control by AO or common objective. One such force design and experimentation pertaining to the multi-domain battle concept is the multi-domain task force (MDTF).[34] A MDTF would be deployable and provide the fire power to create the freedom of manoeuvre in a conflict. [35]

One of the issues with MDO is coordinating a so called MDTF to execute the plans. In MDO, there will be a need to have a Multi Domain Tasking Process in order to synchronize over a specific Area of Operations (AO) or against a certain objective.

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[31] *Ibid.,* 26.

[32] Joint Air and Space Conference Perceding, "Preparing NATO for Joint Air Operations in a Degraded Environment", Joint Air Power Competence Center, 2016, 24.

[33] Airforce TV "Demystifying Multi-Domain Command and Control, 2019 Air, Space & Cyber Conference" 20 Sep 2019. https://www.youtube.com/watch?v=8zgZWiomzas

[34] Perkins, David G.(Gen US Army), "Multi-Domain Battle: The Advent of Twenty-First Century War", Military Review, Nov-Dev 2017, 12.

[35] *Ibid.*, 12.

Currently, the Air Domain uses the Air Tasking Order (ATO) to synchronize and task air assets. This leads us toward the need for a 'Multi-Domain Tasking Order (MDTO)' that would have familiar wording, text and instructions. The problem of having a MDTO is deciding on a common operational lexicon that would be used. This common lexicon must be established to enable communication and collaboration between various organizations and services.[36] Thus this leads towards the need to establish an ability to conduct Cross Domain target sharing in order combine the individual domains' effects and capabilities.

TACTICS- MULTI DOMAIN WITH COMBAT CLOUD

Cross Domain Target Sharing

As mentioned, the major problem would be how to translate this common lexicon to the tactical operators. One solution is by using the Military Kill Chain lexicon; Find, Fix, Track, Target, Engage, Assess (F2T2EA) to conduct MDO target sharing. By using Cross Domain targeting, the kill chain would not solely be executed by one domain. Different segments of the kill chain could be accomplished by different Domains. For example, the 'Find and Fix" segments could be conducted by one Domain, while the Track, Target, Engage and Assess could be conducted by two different Domains.

By using a matrix that is shared across a network at near-instantaneous time, this could provide a simplified method of using cross domain action to complete the kill-chain. **Error! Reference source not found.**, shows a simplified presentation how the Cross Domain process could be conducted. There could be other variations of the

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[36] Flack, Nathaniel, "Self-Directed Learning …752.

scenario using targeting matrix as long as the information is understood by the various domains. From a Unified Command center, one could monitor or even assign various domains to fulfill and execute the MDO Targeting Matrix.

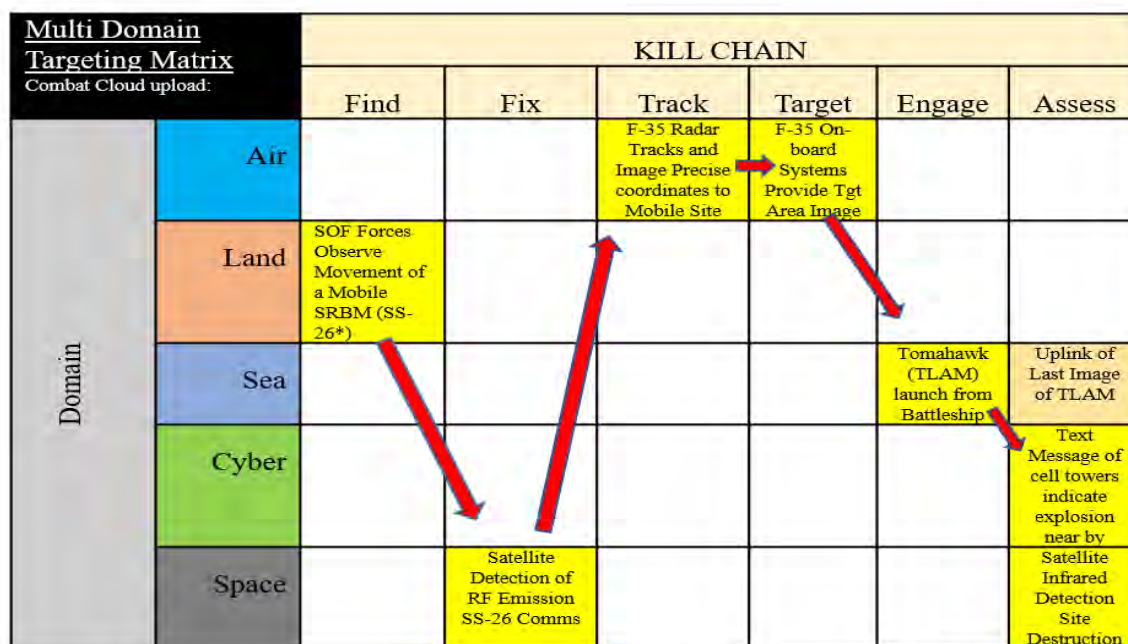| Multi Domain Targeting Matrix Combat Cloud upload:		KILL CHAIN					
		Find	Fix	Track	Target	Engage	Assess
Domain	Air			F-35 Radar Tracks and Image Precise coordinates to Mobile Site	F-35 On-board Systems Provide Tgt Area Image		
	Land	SOF Forces Observe Movement of a Mobile SRBM (SS-26*)					
	Sea					Tomahawk (TLAM) launch from Battleship	Uplink of Last Image of TLAM
	Cyber						Text Message of cell towers indicate explosion near by
	Space		Satellite Detection of RF Emission SS-26 Comms				Satellite Infrared Detection Site Destruction

Figure 4: Multi Domain Targeting Matrix

* Iskander-M or SS-26 is a mobile Short Range Ballistic Missile system that is capable of engaging targets 400-500km away. It is a Vertical launched missile with conventional or nuclear warhead. Guidance is by inertial/satellite with Circular Error of Probability (CEP) of 10-30 meters[37]

In the example of figure 4, a forward deployed team of SOF observed the movement an Enemy SS-26 Short Range Ballistic Missile in their vicinity (Find). Then Satellite orbiting above is able to detect the RF emission of the SS-26 communication and provide general location (Fix). Then an F-35 fighter aircraft could radar map the location to pinpoint the Short Range Ballistic Missile (SRBM) with its SAR capabilities (Track &

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[37] Website Article, "Russia's Anti-Access Area Denial", Missile Defense Advocacy Alliance, https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/russia-anti-access-area-denial-coming-soon/#_edn1

Target). The coordinates and identification could then be picked up off the network and a Navy Battleship could engage the enemy SRBM with a Tomahawk Land Attack Missiles (TLAM) from offshore (Engage). All this action could then be monitored by Cyber Forces that would be focused on the local cell towers to observe any chat or text messages about an explosion nearby the target (Assess).

This scenario challenges the MDO concepts and pushes the requirement for all domains to have a high situational awareness of the battlespace. Only a complex network and process would allow for such rapid sharing and targeting in a fluid operation. In order to have this ability for rapid and redundant sharing of information, a network referred to as the 'Combat Cloud' would be required.

Combat Cloud

The key to assuming that MDO could be a viable option to fighting in the A2/AD environment is the development of an advanced network. A network that can provide synchronization, collaboration and sharing during real-time operations. The concept called the Combat Cloud is that next network or data-link for all domains that will have the distribution and sharing capability required. A mass network that integrates complementary capabilities into a single, combined weapons system to conduct disaggregated, distributed operations over a fluid operational area.[38]
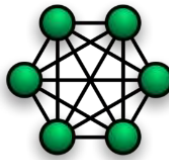
The Combat Cloud would be a federation of airborne and ground-based systems (nodes) that gather, process, store, and disseminate information.[39] The Combat Cloud is based on the concept where every object and person is a component, a router, and a node in a real-time IP based constellation.

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[38] Deptula, David (Lt Gen), "Intelligence, Surveillance and …website
[39] Hostage III, Gilmary Michael and Larry R. Broadwell, Jr., "Resilient …202.

The main objective of the Combat Cloud is to provide low enough latency to enable accurate effects against priority targets.[40] The other goal of a fully connect network such as the Combat Cloud is to ensure redundancy and security from attack or degradation. No vital node or nodes exist, eliminating the single-point weakness of a central repository.[41]

$$c = \frac{n(n-1)}{2}$$

Equation 1:Number of Fully Connect Networked

Thus in a fully connected network, all nodes are interconnected. In graph theory this is called a complete graph and the redundancy is linked to number of nodes because the number of connections grows quadratically with the number of nodes as seen in Equation 1. Nodes can be aircraft, command centers, ships or even individual soldiers in the field. A fully connected network doesn't need to use packet switching or broadcasting.

> *Every node in the battlespace has agency. Where 'agency' denotes the ability to take action and nodes have the capacity, to a greater or lesser extent to act via the OODA loop.*[42]

The ability to connect nodes can be done by satellites or Airborne platforms. The USAF has three Global 6000 aircraft, designated as Battlefield Airborne Communication Nodes (BACN). The BACN is designated as the E-11A provides an airborne communication relay and gateway system. It enables real-time information to flow across

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[40] Deptula, David "Evolving Technologies in the 21st Century: Introducing the 'Combat Cloud'", Mitchell Institute Policy Papers. Volume 4 (September 2016).
[41] Hostage III, Gilmary Michael and Larry R. Broadwell, Jr., "Resilient …202.
[42] Gibson, James, "Re-Imagining delivery of a 5th Generation ADF", Australian Defence Magazine, vol. 27, No.9, September 2019, 26.

the battle space between similar and dissimilar tactical data link and voice systems through bridging and data transmission in line of sight and beyond line of sight situations.[43] The BACN is an example where 4th and 5th Generation Fighters could be able to share information in order to conduct MDO (Figure 5).
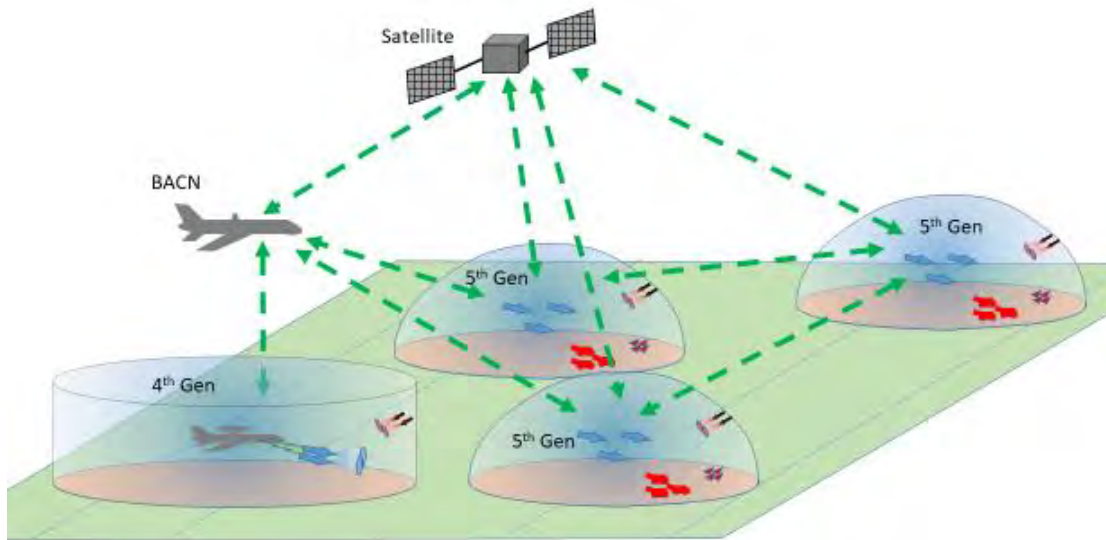

Figure 5: Airborne Nodes -Combat Cloud

Shared Battlespace Method

The last of the key success of integrating MDO through out all domains is deciding on how to separate the Battlespace. In the Air Domain, there are Airspace Coordination Measures (ACM) that separate the airspace into highways of the air. When the Air Domain interacts with the Land Domain there are Fire Support Coordination Measures (FSCM) that delineate ground force operations from Air Operations that are conducting Air to Ground attacks. The question of how the Space Domain will delineate

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[43] Richards, Avid L. (Capt USAF), "Update from the Source- BACN Update",Family of Gateways Requirements Branch, Global Cyberspace Integration Center , 28 Jul 2009, https://web.archive.org/web/20120422094233/http://www.afc2ic.af.mil/news/story.asp?id=123160766.

from the Cyber Domain and how the Cyber Domain would delineate from the Sea
Domain is unanswered.

For the three traditional domains; Land, Sea and Air, the use of the Global Area
Reference System (GARS) will provide a simplified method of coordinating cross
domain effects. GARS provides a common language to describe 30nm x30nm, using
WGS84 latitude and longitude. It can be broken down into 15nm x15nm, and 5nm x5nm
areas by a simplified number and letter system (ie 207LS23) as seen in **Figure 6**. GARS
is universal across the world which can then be translated into blocks of airspace by
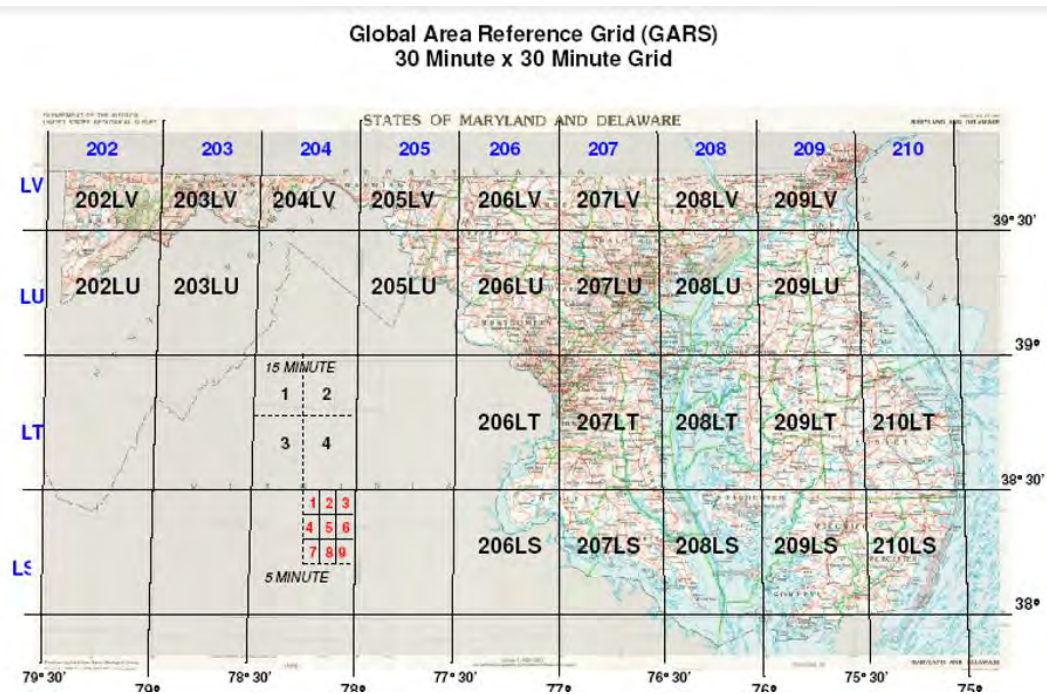3000m or 10000ft for universal coordination.

Figure 6: Example of Global Area Reference System (GARS)

These blocks, much like the online computer game Minecraft, would simplify the
sharing of physical volumes of the Battlespace through a network. As seen in **Figure 7**,
the targeting of multiple threats can be rapidly displayed on a common Multi-Domain

display. Perhaps with the addition of Virtual Reality goggles[44] commander could observe this MDO being executed in real time.
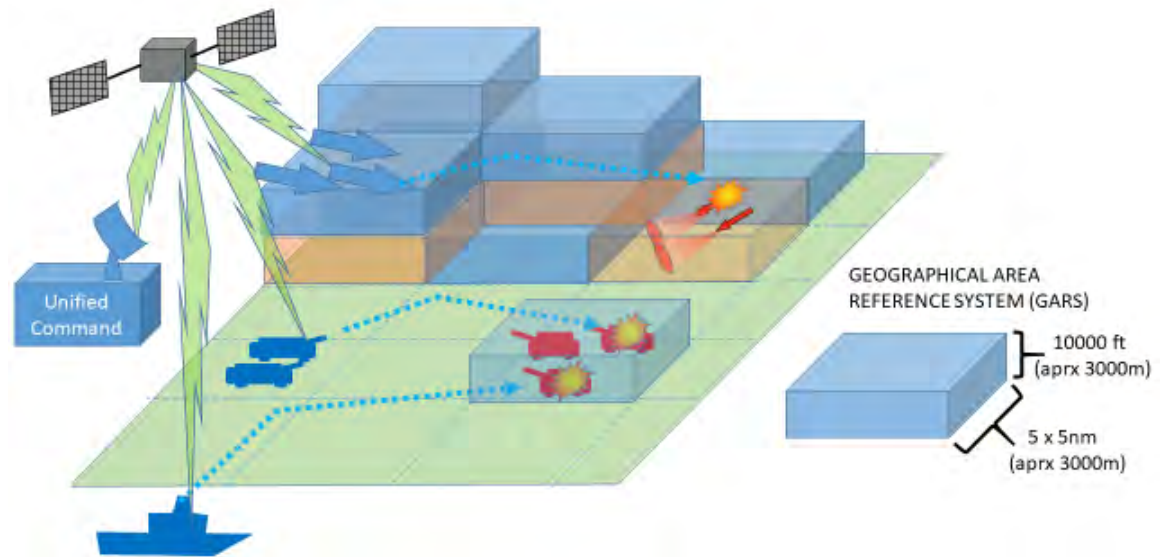

Figure 7: GARS Multi Domain Network Sharing

RCAF Lead Turn MDO

There are several steps that the RCAF could take to further the potential develop and integration of fighters in MDO. The first will be an assumption that the Future Fighter Capability Project (FFCP) will deliver a fighter capable of cross domain target sharing, either through an advanced network or the incorporation of a 'Combat Cloud' technology, yet to be developed.

The backbone of the discussed fighters' integration into MDO was the ability to transfer data through satellite. There will be a need for the ability to share multitude of sensor information over a secure network with high precision and accuracy at a high data

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[44] Raytheon, "Raytheon shows off Multi Domain operations battle management at Farnborough Airshow 2018". Breaking Defense YouTube Channel, 17 Jun 2018. https://www.youtube.com/watch?v=ouK87PFD7vA&t=98s

rate[45] via satellite to a ground station. Currently, this means that there would be a requirement to use the Mobile User Objective System (MUOS),[46] a narrowband military communication satellite to relay the information from the 4th Gen Fighters to a ground based ABM for over the horizon operations. CF-18 Fighters that will be flying to 2032 will need to have a satellite antennae capable of uplink/downlink and maintaining connection with MUOS.

While not specifically aimed at the capabilities of 5th Generation Fighter, any future RCAF projects that will delivery combat capable aircraft will need to consider MDO concepts and 'Combat Cloud' technology into their requirements. The RCAF projects such as Remote Piloted Aircraft System (RPAS), Canadian Multi-Mission Aircraft (CMMA), and Multi Role Tanker Transport (MRTT) all could provide airborne network connectivity and contribute to MDO through the Combat Cloud. For example, the MRTT, which is a future AAR aircraft could be configured to provide an Airborne ABM while also transferring fuel to fighter aircraft. This would be an advantage where there is a contested satellite AO.

Leaving the previous mindset of traditional fighter control behind in the past, the RCAF will have to modify the training of its Aerospace Controller Officers to think in the cross domain. There would be a need to change the GCI's scope, the screen which plots and displays airborne tracks in real time. This means the current GCI scope would require some changes with respect to data processing in order to display an Air and Surface Operating Picture. This is quite different from the traditional Common Operating

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[45] "Mobile User Objective System," *Wikipedia The Free Encyclopedia*, (last update:7 June 2019) https://en.wikipedia.org/wiki/Mobile_User_Objective_System
[46] *Ibid.*

Picture (COP). With the overlay of surface features being as important to the air display. That also means that ABM teams would focus on Air and Surface information.

How We Will Fight in the CAF

The MDO concepts will require some specialized strategic to tactical planning with the use of an enhanced network to exercise cross domain targeting. The development of non-theatre specific training programs, would allow operators to become experts in fully integrating not only airpower but the other domains while practicing MDO concepts.[47] By investing in world-class synthetic training for all appropriate practitioners,[48] the CAF could move forward with the integration of 5th Gen Fighters to MDO. Besides the lack of cross domain training in the CAF, additional steps to develop the MDO doctrine would need to be addressed at the CAF Joint Warfare Center.

> The Air Force, through the Air Combat Command (ACC), is committed to conducting multiservice exercises, experiments, and war games on multi-domain battle to increase shared understanding and visualization.[49]

Currently in the CAF, the fact that cyber and space are not exclusively military domains complicates planning and campaign design for MDO. For example, there is a flaw in combining air and space domain into the one environmental element under the RCAF. This is because the Space Domain is unique and demands a distinct and considered approach to conduct operations within it.[50] The CAF should embrace this opportunity to develop focused and robust space-operations doctrine.[51]

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[47] Wright, A.J. (Wg Cdr RAF), "How We Fly", Joint Services Command and Staff College, Defence Research Pager, Jul 2013. 36.

[48] *Ibid.,* 36.

[49] Perkins, David G.(Gen US Army), "Multi-Domain Battle: The Advent of Twenty-First Century War", Military Review, Nov-Dev 2017, 13.

[50] Thompson, Major Matthew. "Separating 'Space' from Aerospace: A Case for Canadian Armed Forces Space Doctrine." Royal Canadian Air Force Journal 6, no. 3 (Summer 2017): 77.

[51] *Ibid.,* 80.

CONCLUSION

The A2/AD environment is going to restrict the freedom of movement on the battlefield. Through the execution of Multi-Domain Operations (MDO), forces will be able to synergize their effects across all domains (Air, Land, Sea, Space and Cyber) to create windows of superiority. The Air Domain will be contested by a combination of networked Surface-to-Air Missiles and fighter aircraft, preventing defence to other domains. This Aerial Area Denial will force the Airmindedness of the next generation of Aviators to become accustomed to thinking about information sharing and cross domain targeting in collaboration with other domains.

The development of the Combat Cloud, a future network capable of synchronization during real-time operations will be a federation of airborne and ground-based systems to support MDO throughout the battlespace. 5th Generation fighters, like the F-35, will be capable of generating a combined Air and Surface picture will be one of the keys to success to exploit the simultaneous capabilities of multiple domains of over a specific objective.

The Air Power tenant will change from the current Centralized Control, Decentralized Execution that has been used with 4th Generation Fighters, to a new C2 construct as Unified Command, Distributed Control, Decentralize Execution. Fighter aircraft will be more self-reliant and will execute the concepts of 'Power to the Edge' mentality in order to self-prosecute targets and support against threats to other domains. Air Battle Management will become the replacement for AWACS aircraft and the RCAF will have to adapt it command structure to support a single commander for MDO.

This paper was to answer two specific questions. First, how would an RCAF Advanced Fighter provide warfighting capabilities in an Aerial Area Denial environment

through Multi-Domain Operations. This can be answered with the capabilities that come with 5th Generation fighters and as long as the new fighter can join this advanced data networks. While software and initial concepts would need flushing out, there would a requirement for Aviators of tomorrow to development an expanded Airmindedness. Other efforts towards developing the Cyber Domain and the Space Domain will need additional resources and funding to provided sufficient personnel for MDO.

Last question was; what technological advances and concepts will be required by the Canadian Armed Forces (CAF) in order to benefit from an 5th Generation Fighter in the MDO concept? As explained the 5th Generation Fighter will be the gateway to integration into MDO. The CAF will have to adopt the full jointness of all domains and be able to communicate with an advanced network before it will benefit from MDO.

As the thesis of this paper was to consider how the RCAF will integrate into Multi Domain Operations with Combat Cloud technology while utilizing the advanced war fighting capabilities of a 5th Generation Aircraft to have an operational advantage in the A2/AD environment. There is a lot of technology and investment that would be required to adapt to the changes that are fully envisioned in the MDO concept presented. And 'only through investing in the institutionalisation of cross environment understanding can the true integration of any component be achieved'.[52] The forward looking reality is that transition and training necessary to consolidate MDO would be extensive. Even before attempting to execute MDO in a conflict against an A2/AD capable adversary, 'we must adopt a mindset able to meet this challenge across multiple domains'.[53]

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[52] Wright, A.J. (Wg Cdr RAF), "How We Fly", Joint Services Command and Staff College, Defence Research Pager, Jul 2013. 33.
[53] Canadian Armed Forces, "Pan-Domain Force Employment Concept Prevailing in an Uncertain World", Government of Canada, 2020, 13.

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