# ROYAL CANADIAN AIR FORCE FALL 2019 • VOL.8, NO.4 I

The ROYAL CANADIAN AIR FORCE JOURNAL is an official publication of the Commander Royal Canadian Air Force (RCAF) and is published quarterly. It is a forum for discussing concepts, issues and ideas that are both crucial and central to air and space power. The Journal is dedicated to disseminating the ideas and opinions of not only RCAF personnel, but also those civilians who have an interest in issues of air and space power. Articles may cover the scope of air-force doctrine, training, leadership, lessons learned and air-force operations: past, present or future. Submissions on related subjects such as ethics, technology and air-force history are also invited. This journal is therefore dedicated to the expression of mature professional thought on the art and science of air warfare and is central to the intellectual health of the RCAF. It serves as a vehicle for the continuing education and professional development of all ranks and personnel in the RCAF as well as members from other environments, employees of government agencies and academia concerned with air-force affairs.

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LETTERS TO THE EDITOR	50-250	Commentary on any portion of a previous RCAFJ.
ARTICLES	3000-5000	Written in academic style.
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POINT/COUNTERPOINT	1500–2000	Forum to permit a specific issue of interest to the RCAF to be examined from two contrasting points of view.

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#### CALL FOR SUBMISSIONS

For the Winter issue: 30 October

For the Spring issue: **30 January**For the Summer issue: **30 April** 

For the Fall issue: 30 July

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#### EDITOR'S MESSAGE

This fall 2019 issue of the *Royal Canadian Air Force Journal* provides an assortment of articles that are sure to entice many an air power enthusiast. Furthermore, these articles demonstrate the wide array of issues that the Royal Canadian Air Force (RCAF) deals with on a day-to-day basis. The result should be an understanding of the competing interests at play in operating such a complex organization. It should also lead one to contemplate the professional-development issues facing our new generation of leaders. How do we give our developing officers the bandwidth to lead in this challenging environment? If you haven't asked this question by the end of this issue, then you haven't been reading closely enough.

"Boxtop 22: The Cost of Focusing on an Operational Culture," by Lieutenant-Colonel Rozema-Seaton, delves into the operational culture of the "get-it-done" mentality within the air-mobility community. The challenge of being efficient and the unintended consequences to safety are two of the many issues that the author addresses in his article.

The second article is delivered by Captain Chandler, an Air and Space Power Operations Course (ASPOC) graduate, who attempts to answer the Commander RCAF's question, "Which space-based command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) capabilities can be harnessed by the RCAF to enable air power?" Captain Chandler takes on this issue by discussing the requirement to integrate space-based capabilities into the RCAF's Combined Aerospace Operations Centre in Winnipeg. The C4ISR leverage that can be obtained by the RCAF to enhance its recognized air picture is substantial.

In our third article, Major Dunwoody engages us with "Learning Analytics" as it applies to ensuring the efficient delivery of training within the RCAF. Learning analytics is a process that belongs to the discipline of data mining, sometimes referred to as educational data mining. Its application is intended to ensure the required level of learning at an appropriate resource cost.

In our fourth article, Major Voyer promotes the idea that the introduction of armed, unmanned air vehicles into the Canadian inventory will greatly assist in the development of a national targeting capability. Major Voyer discusses the issue in terms of manned versus unmanned, armed versus unarmed and national versus international contributions.

In our "Points of Interest" article, Captain McGregor, a graduate of ASPOC 1801, discusses machine learning in the RCAF. In particular, he delves into the idea of machine learning to assist in optimizing personnel resources.

Finally, in the "Pushing the Envelope" segment, Sergeant Wells examines the challenges of conflict in space and how the current state of treaties does not address issues that will come into play in the future and the need to address these issues.

So, how do we give our developing officers the bandwidth to lead in this challenging environment? I look forward to your thoughts.

Enjoy the read.

Sic Itur Ad Astra

Lieutenant-Colonel Doug Moulton, CD, MBA

Senior Editor





### BOXTOP 22

The Cost of Focusing on an Operational Culture

By Lieutenant-Colonel Erik Rozema-Seaton



ir power has the potential to provide significant benefits to military missions by leveraging the reach, speed and agility of aircraft. However, with the inherent risks related to flying, these benefits can be quickly negated by one mistake, or through a series of events culminating in an aircraft accident. On October 30,

1991, such an event occurred. A Canadian Armed Forces (CAF) CC130 Hercules aircraft from 435 Squadron, call sign Boxtop 22, departed Thule Air Force Base, Greenland, as part of Operation (Op) BOXTOP and suffered a controlled flight into terrain (CFIT) when its left wing impacted the ground approximately 10 nautical miles (NM)<sup>1</sup> southeast of Canadian Forces Station (CFS) Alert.<sup>2</sup> The aircraft suffered catastrophic damage and three passengers and one crew member died from injuries sustained during the impact, while the aircraft commander (AC) died of exposure approximately 24 hours later while waiting for rescue. Even though one of the most robust domestic search-and-rescue operations in Royal Canadian Air Force (RCAF) history was immediately launched, the remaining crew and passengers endured 47 hours in the harsh Arctic environment before being rescued.<sup>3</sup>

While numerous factors caused or contributed to the events leading up to the crash of Boxtop 22, the "get-it-done" mentality within the air-mobility community stands out as being most significant. This operational focus has the potential to provide substantial benefits; however, it can be equally dangerous if it is the sole focus of the community. Accordingly, this paper will argue that the conditions leading to the crash of Boxtop 22 were created by the RCAF unit-level and institutional leadership's failure to foster a culture of safety and open communication within the crews of the air-mobility fleet.

To provide context, this article will first outline the operational situation and key sequence of events during the Boxtop 22 flight leading up to the CFIT. Using RCAF doctrine and human-performance-in-military-aviation (HPMA) principles as analytical constructs, this article will examine the cultural and crew-coordination hazards and errors that occurred during the flight of Boxtop 22. Within the framework of the current CAF leadership doctrine, the article will then demonstrate the RCAF senior leadership's failure to foster a culture of operational safety, ensuring crew training and safe operating principles were effectively promoted to assist in reducing the risks inherent in RCAF operations. Finally, the article will analyse several of the actions RCAF senior leadership has taken since the accident occurred and provide an assessment of the lessons learned from this tragedy.

While numerous factors caused or contributed to the events leading up to the crash of Boxtop 22, the "get-it-done" mentality within the air-mobility community stands out as being most significant.



A CC130 Hercules parks on the flight line waiting for their next flight out to Alert in Thule, Greenland, during Op BOXTOP on April 27, 2017.

#### KEY OPERATIONAL EVENTS

Located 441 NM from the geographic North Pole, CFS Alert is the most northerly, permanently inhabited location in the world.<sup>4</sup> To sustain station operations, the CAF conducts Op BOXTOP twice a year to supply the station with the materials and equipment needed for up to six months. Supplies are shipped by sea to Thule Air Force Base and then flown to CFS Alert, a role for which the CC130 Hercules is ideally suited.<sup>5</sup>

On October 30, 1991, the crew of Boxtop 22 (the 22nd scheduled flight for Op BOXTOP) prepared for their 4th flight of the operation. Op BOXTOP had been running for three days and the crews were starting to get into the flight routine and adjusting to the nearly 24 hours of darkness.<sup>6</sup> The pre-flight preparations were uneventful, and at approximately 1520 local time, Boxtop 22 took off for its 1 hour and 20 minute flight to CFS Alert. Approximately 100 NM from their destination, the crew prepared and briefed for the arrival. They then contacted the approach-radar operator at CFS Alert—call sign Glow Worm—that was temporarily in operation for Op BOXTOP. The first officer (F/O) made radio contact and Glow Worm confirmed their position at 92 NM south of Alert and advised them they could initially descend to 3,048 metres (m) above mean sea level (MSL).<sup>7</sup>

At the same time that Boxtop 22 was in its initial decent, Boxtop 21 was making its own preparations for arrival into Alert. Boxtop 22 took off on schedule, while Boxtop 21 was delayed on the ground in Thule due to a mechanical malfunction. To keep the flow of the operation going, Boxtop 22 took off as planned and Boxtop 21 followed twenty minutes later. This separation now posed a potential problem. With Boxtop 22 in descent, Boxtop 21 twenty minutes behind, and Boxtop 20 already on the ground in Alert, there was a possibility that all three aircraft would be on the apron in Alert at the same time. The Boxtop 22 AC saw this situation developing and, to try to reduce congestion in the limited space on the apron, decided to attempt to speed up his arrival. He reasoned that by landing earlier, he could be further ahead in his fuel offload, and maybe even be completed prior to Boxtop 21 landing. To expedite the arrival, the AC decided to switch to a visual approach. The F/O made the appropriate radio calls and Glow Worm acknowledged and cleared them for the visual approach.

In the transition to visual procedures, the AC switched his horizontal situation indicator (HSI) from tactical air navigation aid (TACAN) to heading mode. With this switch, his HSI primary steering needle no longer pointed to the TACAN at the airfield, eliminating one of his situational-awareness resources. Comfortable that the crew was set up to continue the arrival, the AC continued the descent to 1,189 m MSL. The crew looked ahead as the lights of the airfield grew in the windscreen. What they were experiencing was a black-hole optical illusion created by the clear winter conditions, with objects appearing remarkably closer than they were. With their belief that they were closer to the airfield than they really were, they turned off course to set up for the downwind leg of the approach.<sup>9</sup>

As they continued downwind, the pilot asked the navigator if it was safe to descend to the circuit altitude of 457 m MSL. Using his radar scope, the navigator looked ahead and saw a black picture with minimal radar returns, indicating that they were over water. In reality, what the navigator was seeing was a phenomenon called radar reversal and, without cross-checking his TACAN indicator to verify their position, the navigator confirmed that they were over the water and that 457 m MSL was a safe altitude. The navigator was correct in that, if they were over the water, 457 m MSL would have been a safe altitude. However, the gentle rolling hills below them were still topped at 366 m MSL, giving Boxtop 22 only 91 m of clearance from the peak of the hills, not the 457 m required by regulations. As the aircraft continued to descend, the AC reduced the throttles and slowed the airspeed to 160 knots and lowered the flaps to 50%. Although he called reaching 457 m MSL, no other crew member alerted him that the aircraft had slipped below and was actually at 396 m MSL.



Cairn dedication to mark the 25th anniversary of the crash of Op BOXTOP Flight 22, the event was on the crash site, approximately 16 kilometres south of CFS Alert on June 15, 2016.

## The crash of Boxtop 22 is an unfortunate example of how a chain of events and mistakes can lead to a disastrous ending.

Approximately 12 NM southeast of the airfield, the crew of Boxtop 22 thought they were closer to the airfield, higher than they really were, and geographically located safely over the water and not above the rolling Arctic hills. As the crew continued to fly the downwind leg of the approach and performed the procedural landing checks, the aircraft "veered slightly to the right, just enough for the airfield lights to disappear behind the left outboard engine." The AC steered left, dropping the left wing 20 degrees expecting that this would bring the lights back into view.

At approximately 1625 local time, as the aircraft turned, the left wing initially hit the crest of a small mountain, followed by the underside striking the ground. Boxtop 22 travelled along the ground for approximately 488 m, splitting into three sections and careening in a large circle before coming to a halt. The series of minor, unchecked errors initiated at the top of descent resulted in the crew and passengers of Boxtop 22 crashing into the high Arctic. Ultimately, these errors resulted in five crew and passenger fatalities, multiple casualties, the destruction of the aircraft and the largest domestic search-and-rescue efforts in RCAF history, requiring 47 hours to reach the crash site. While many of the failures leading up to this accident were the result of human error, further analysis showed that underlying cultural issues within the air-mobility community played a significant part.

#### **HUMAN-ERROR MODELS**

Modern crew-resource-management (CRM) concepts date back to the early 1980s when a number of studies were undertaken to determine if commonalities could be found between aircraft accidents.<sup>15</sup> These studies found that a number of commonalities did exist, and that a series of preventative measures could be used to help aircrew avoid the preconditions for aircraft accidents. While a few of the CRM-related research and theory principles had been implemented within RCAF operating procedures, the RCAF did not fully embrace and apply these principles to its doctrine and training policies until late in 1993. 16 Psychology professor James Reason contributed to the development of modern CRM principles with his theory on human error. Reason argued that "humans are fallible and errors are to be expected, even in the best organizations." In response to this, Reason developed the "Swiss cheese" model of human error and argued that, "though we cannot change the human condition, we can change the conditions under which humans work." <sup>17</sup> Within this systems approach to human error, the strategies employed concentrate on building defences to avert errors. These defences, barriers and safeguards are intended to avoid, trap and mitigate potential errors and threats.<sup>18</sup> The overall effectiveness of the tactics used relies on the cultural acceptance of these principles within the organization, such as a safety-oriented attitudes and valuing open communication.<sup>19</sup>

The overall mentality of CC130 transport aircrew was to get the job done, and was fueled by the difficult conditions and challenging types of operations that Hercules aircraft and crews were called upon to perform.

#### CONTRIBUTING FACTORS

The crash of Boxtop 22 is an unfortunate example of how a chain of events and mistakes can lead to a disastrous ending. Applying Reason's model to the events of this accident assists in defining the contributing factors that led to the sequence of errors not being corrected. The cultural and organizational influences within the Air Transport Group at the time can also be observed through the crew's acts of unsafe supervision, lack of information verification and poor crew communication. It was these simple yet critical layers of defence that either failed or were absent during the arrival of Boxtop 22, which culminated in its CFIT.

As a military organization, the Air Transport Group was focused on conducting operations and effectively completing assigned tasks. The overall mentality of CC130 transport aircrew was to get the job done, and was fueled by the difficult conditions and challenging types of operations that Hercules aircraft and crews were called upon to perform. This attitude can potentially help in achieving high levels of success in military operations by challenging crews to operate effectively and push them to continue in difficult situations by building a heightened sense of purpose. However, this attitude can also have negative effects if the plan is not thoroughly coordinated and if all factors are not suitably accounted for. The principle that increased risk is only acceptable if there is an associated benefit outweighing the potential cost of the risk is significant in this situation. The crew of Boxtop 22 was flying as part of a team participating in a military resupply operation. Being involved in Op BOXTOP did not automatically authorize the crews to accept additional levels of risk. However, being part of an operation does fuel the desire to accomplish the mission and to accomplish it effectively. The following points illustrate errors or decision that were made by the crew members that inherently increased the risk of the arrival procedure and were not balanced by a higher level of attention or other attenuating actions.

During all phases of training, aircrew are taught to anticipate situations and to develop solutions to address potential problems. This process of looking forward and attempting to save time, rather than prioritizing the safety of the aircraft and crew, is one of the initial factors in the series of events leading to the crash. The AC had initially prepared for an instrument approach into Alert and set his instruments accordingly during the arrival briefing. After starting the descent, he foresaw the potential congestion on the apron and thought of a course of action that could alleviate



A CC130 Hercules aircraft takes off from Thule Air Base, Greenland, to conduct fuel runs to Alert, Nunavut, during
Op BOXTOP on October 6, 2016.

this problem. By changing the approach from an instrument to a visual pattern, he would save time and most likely effect a more efficient operation by limiting the level of congestion on the Alert apron. The last-minute decision to change the approach, however, would save no more than five minutes and this was not adequately weighed against the additional risk the changes added.<sup>23</sup> This thought process was consistent with the way air-mobility crews were trained. It was instilled within their culture to look for opportunities to save time and make the mission more efficient.<sup>24</sup> The downside of changing to a visual approach was that it removed several of the situational awareness resources at the crew's disposal that would have been present during an instrument approach. It is possible that the AC perceived the benefits of a faster arrival to outweigh the increased risk of a night-visual approach in an area of high terrain. However, this would only have been acceptable if the additional risk assumed was countered with a higher level of attention during the approach.<sup>25</sup>

One of the approach procedures used within air mobility to provide a higher level of supervision is called the pilot-monitored approach. The benefit of the pilot-monitored-approach procedure is that it provides the more experienced AC the opportunity to supervise and direct the crew without also having to concentrate on controlling the aircraft. Additionally, this procedure affords the F/O the opportunity to develop flying skills and gain more valuable aircraft-control experience. The AC of Boxtop 22 significantly reduced the benefits of the pilot-monitored-approach procedure by taking control of the arrival during the descent and transferring the monitoring duties to the F/O. While not a procedural-orders violation, this action highlights the reduced level of concern the AC had for the conditions of the arrival and a failure to recognize the increased risk he had assumed by flying the visual approach. By flying the approach himself, the AC reduced his ability to monitor and effectively communicate with other crew members. This is of particular concern as it was the first night-visual arrival for the crew during the operation. <sup>26</sup>

Current RCAF HPMA principles highlight communication as a critical aspect in the operational decision-making process as well as a key tool in hazard, threat and error management.<sup>27</sup> Throughout the arrival of Boxtop 22, poor communication was demonstrated on multiple occasions and can be primarily attributed to the hierarchical practice within air mobility of traditionally not questioning decisions. An important aspect of crew communication is to ensure all crew members share the same goals, perceptions and mental model.<sup>28</sup> During the arrival, while not unreasonable, the change to the visual approach was not questioned and it is not certain that all crew members were aware of the increased risk involved. On several occasions during the approach, the F/O, navigator and flight engineer did not voice their doubts or concerns about a decision or action the AC was taking. Of critical significance was the AC descending below MSL, which was briefed as the minimum safety altitude. Had one of the crew members vocalized the error and demanded an immediate correction be made, it is most likely that, even though the aircraft was still below the actual safe operating altitude of the area, the aircraft would not have hit the mountain.

## It can be seen that a key component in conducting safe air operations is fostering a culture of safety throughout the organization.

In addition to staunching communication within the crew, the customs within air mobility impacted less experienced crew members' confidence in challenging the decisions of and information provided by more experienced crew members. This was particularly true when the more experienced crew member was the AC.<sup>29</sup> This philosophy brings about additional challenges in that it can create a sense of faith that may lead to information from the senior crew member being explicitly trusted rather than being cross-checked with other information. On several occasions during the approach of Boxtop 22, the developing unsafe situation could have been stopped by crew members properly cross-checking information with other navigation sources. Current HPMA principles outline this as trapping errors, and reinforcing this principle in the air-mobility culture would have most likely assisted in avoiding this tragedy.<sup>30</sup> While the errors that occurred on Boxtop 22 that contributed to the aircraft's CFIT are attributable directly to the crew members involved, the senior RCAF leadership was also responsible for playing a part in the accident.

#### INSTITUTIONAL INFLUENCES

Within the accident investigation closing action report is the powerful statement that "this was a preventable accident."<sup>31</sup> This statement is more profound in that was made by the Commander of Air Command, Lieutenant-General Huddleston, and while it was intended to reflect on the actions taken and errors made by the crew of Boxtop 22, it also holds true when applied to the RCAF leadership prior to the accident. CAF leadership doctrine outlines the requirements of CAF leaders to achieve mission success not only by leading the people at the unit level but also by leading the

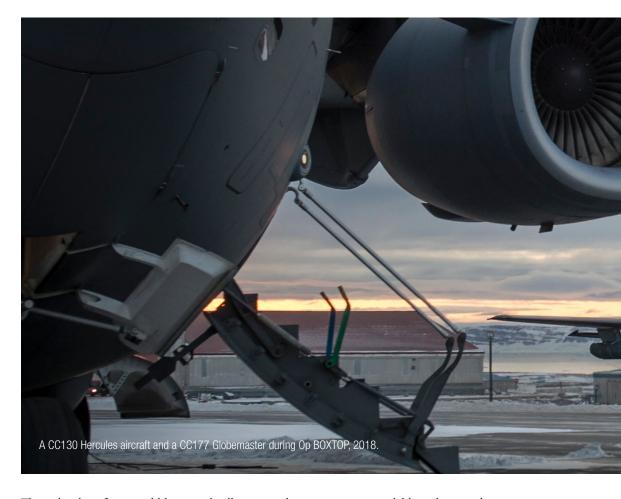
institution. CAF senior leaders are responsible to ensure that the necessary operational capabilities are created, while also developing and maintaining a professional identity and aligning culture with ethos. Operational focus is a key factor; however, this must be balanced by the leadership fostering an environment of learning and collaborative relationships in order to increase effectiveness and support personnel well-being.<sup>32</sup>

Using this leadership framework, it can be seen that a key component in conducting safe air operations is fostering a culture of safety throughout the organization. Prior to the crash of Boxtop 22, the approach within Air Transport Group encouraged the "get-it-done" mentality as well as "a degree of wilful disobedience to flying by the rules" being accepted if it achieved operational results.<sup>33</sup> Exploits that pushed the envelope, or challenged an aircraft and its crew to the limits, held a degree of heroism within the community. This came with a willingness to accept higher risks in order to be more operationally effective. The failure to prioritize safety within the organization at the time was demonstrated by the Air Transport Group not fully embracing safety-related training, by conducting Op BOXTOP during a higher-risk time period and by not ensuring the aircraft was equipped with modern ground-proximity warning equipment.<sup>34</sup>

While the Air Transport Group did provide aircrew with safety-equipment briefs and survival training, they were not mandatory to conduct operations. For the crew of Boxtop 22, none of the members had completed Arctic survival training. A safety-minded outlook would not have supported personnel operating in an environment in which they had not had appropriate training. Additionally, CRM- and HPMA-related training had not been embraced by the RCAF prior to the accident, even though its benefits had been recognized during the previous decade within the United States. Multiple opportunities were presented during the approach into CFS Alert when CRM and HPMA training principles and techniques could have helped to avoid, trap or mitigate the errors made by the crew. The removal of any one of the errors could have halted the sequence of events leading to the CFIT.

An additional organizational influence that affected the crew of Boxtop 22 was the decision to conduct Op BOXTOP during a period of complete darkness in the Arctic. By planning on operating between the end of October until the middle of November, Air Transport Group leadership increased the level of mission risk by removing the safety benefits of daylight operations (better visual navigation cues, less effect on circadian rhythms).<sup>37</sup> Fuel logistical restraints at CFS Alert did play a part in the decision of Op BOXTOP to be conducted later in the year; however, there were still opportunities to complete the operation during a period of partial daylight. Conducting the operation two weeks earlier would have afforded the crews the ability to operate in a period of twilight, and a month earlier would have allowed for approximately 12 hours of daylight.<sup>38</sup> Op BOXTOP is now conducted exclusively during times of the year that experience periods of 24 hours of daylight.<sup>39</sup> Additionally, the higher level of risk accepted by conducting the operation during a period of complete darkness could have been reduced by reinforcing safe operating practices as well as highlighting environmental hazards (i.e., optical illusions) through refresher training prior to the commencement of the operation. These factors are now addressed for Op BOXTOP with safety-awareness and optical-illusion refresher training incorporated into the initial operation brief provided to crews prior to the start of flying operations. 40

While the lack of focus on safety training was concerning, the RCAF senior leadership had an opportunity to reduce operational risk by providing modernized equipment and information displays onboard the CC130. While a radar altimeter (RADALT) was installed on the Hercules, the warning light was located in a position outside of the pilot's normal "T" instrument scan.



The technology for an audible ground collision avoidance system was available at the time; however, it was not a procurement priority. HPMA principles highlight that a more suitable location for the RADALT warning light or the installation of a vocal ground-proximity warning system could have proved instrumental in avoiding the accident.<sup>41</sup>

It was observed within the closing action report that this accident was the third aircraft that had suffered a CFIT in less than two years under night-visual flight rules. <sup>42</sup> It is unclear why RCAF senior leadership was not alerted by the potential trending of these accidents; however, the lack of addressing the apparent common factors among these accidents demonstrates that the mindset within the Air Transport Group was more focused on operational achievement than on safety.

#### IMPACT

While the events that occurred on the evening of October 30, 1991, are tragic, there are several positive outcomes that have resulted from the lessons identified from the accident. Within the closing action report, a significant number of the cultural and leadership failures were recognized as contributing factors, and measures were put into effect to correct these deficiencies. These measures included a review of the survival-gear storage, equipment-use training, crew equipment accessibility as well as mandatory Arctic survival training for aircrew that routinely operate



in that environment. Additionally, the merits of fostering values that embrace the CRM and HPMA principles were recognized and the training became a mandatory part of crew continuation training in September 1993. CRM principles played an additional role during the avionics update programme, as the information display layout was reassessed and the installation of a ground collision avoidance system was initiated in 1994. Overall, the lessons learned from this disaster acted as catalysts for safety reform within the Air Transport Group. It was recognized that many of the potential corrective measures were already available prior to the accident, as they were highlighted in the closing action report. The real tragedy is that it required an accident of this magnitude for RCAF leadership to recognize the need for a cultural shift within the organization and to focus on and embrace a culture of safety.

#### SO WHAT?

A focus on safety and open communication is paramount within the current and future RCAF operational environments. Over the past two decades, these values have been continually developed; however, vigilance is required to ensure operational focus is maintained without sacrificing safety. In the future, RCAF doctrine's air power tenet of centralized control and decentralized execution will continue to play a major role in conducting operations, which will in turn continue to place decision making and risk acceptance in the hands of less experienced mission and

aircraft commanders. Lower experience levels, personnel shortages, ageing aircraft, and operating in demanding environments will continue to challenge the RCAF and will require a disciplined, professional force in order to achieve mission success. More importantly, however, a culture of safety is necessary to ensure member well-being and sustain capabilities for future requirements. Personnel will continue to be the most valuable resource within the RCAF,<sup>44</sup> and the people that step up to accept the multitude of daily challenges deserve to be supported accordingly.

The demand for air power is as high as ever, with CAF operations being supported both domestically and around the globe. As outlined in the most recent Canadian defence policy, this trend will continue. To meet these demands, it is critical that senior leadership promotes safety and open communication throughout the RCAF. Embracing these habits does not advocate risk avoidance, but rather accepts risk at the right times and at the appropriate level. Accepting risk should only be done when necessary, when available mitigating measures have been taken and only when the benefits of accepting that risk outweigh the potential costs. A focus on operational safety facilitates this process and empowers critical decision making by providing a balance against operational pressures. Furthermore, open communication fosters an environment where personnel are comfortable to identify their concerns and recommendations, enabling constructive dialogue to occur. To ensure mission success as well as protect the well-being of RCAF members, safety and open communication must be embraced throughout all fleets.

The previous points are not intended to argue that a focus on safety is currently lacking within the RCAF, but rather to reinforce that this ethos is more important than ever. High release rates are reducing experience levels across numerous trades, and the associated personnel shortages are resulting in higher individual workloads. The increased use of automation is able to alleviate some of the associated risk; however, a high degree of diligence, teamwork and communication is required to be effectively employed. On many occasions, achieving operational objectives will continue to necessitate that personnel be creative and take on significant challenges and additional risk. A culture of safety will enable reaching these goals effectively while protecting personnel and preserving future operational capabilities. There is little doubt that the professionalism and inherent drive of RCAF members to "get it done" will continue; however, in the greater interests of the RCAF and its members, this must be balanced with a focus on safety and the proper application of risk management.

Personnel will continue to be the most valuable resource within the RCAF, and the people that step up to accept the multitude of daily challenges deserve to be supported accordingly.



Parade to mark the 25th anniversary of the crash of Op BOXTOP Flight 22 at CFS Alert on June 15, 2016.

#### CONCLUSION

The use of air power in military operations is widely considered to be a force multiplier and can provide significant advantages when employed effectively.<sup>47</sup> However, safety considerations need to be carefully balanced against the risk and operational benefits to ensure the well-being of personnel and long-term sustainability of equipment. The fate of the crew of Boxtop 22 and aircraft CC130322 is a testament to this. Their legacy lives on as a reminder that a series of avoidable human errors can ultimately have disastrous consequences. The accident also serves as a reminder that it is not only the actions of one person or the collective actions of a crew that contribute to the sequence of events leading up to an accident; organizational leadership also has a key role to play. While numerous issues caused or contributed to the events leading up to the crash of Boxtop 22, the primary conditions contributing to the accident were created by the RCAF unit-level and institutional-leadership failure to foster a culture of safety and open communication within the crews of the air-mobility fleet.

Throughout the flight of Boxtop 22, there were several occasions when the accident could have been avoided through the use of CRM principles, such as clear communication, effective teamwork and information cross-checks. Additionally, RCAF leadership could have assisted in preventing this incident by ensuring the aircrew was provided updated training and modernized equipment. While it is not possible to reverse the events that occurred on October 30, 1991, it is possible to ensure that the lessons learned that evening are passed on to future generations of aircrew, and a similar set of circumstances avoided through the continued recognition of balancing operational pressures with a culture of safety. The RCAF cannot afford to pay the cost of learning these lessons again.

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#### **ABBREVIATIONS**

**AC** aircraft commander

ACSO air combat systems officer
CAF Canadian Armed Forces
CFIT controlled flight into terrain
CFS Canadian Forces Station
CRM crew resource management
DND Department of National Defence

**F/O** first officer

**HPMA** human performance in military aviation

MSL mean sea level
Op operation

**RCAF** Royal Canadian Air Force **TACAN** tactical air navigation

#### NOTES

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  - 10. Huddleston, Closing Action Report, 4.
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## SPACE:

HOW TO INCORPORATE SPACE DATA INTO AIR OPERATIONS TO ENSURE THE ROYAL CANADIAN AIR FORCE REMAINS CREDIBLE AND RELEVANT

BY Captain melissa chandler



**Editor's note:** This paper was written by a candidate attending the Air and Space Power Operations Course in fulfilment of one of the requirements of the course of studies.

or those working within the defence community, it is increasingly apparent that the role of space is becoming ever more important with respect to current military operations. Space provides defence forces with greater situational awareness (SA), allowing for superior intelligence gathering in support of various mission sets, including, but not limited to, targeting and missile defence. Despite modern warfare's full spectrum of combat operations, including the critical role of space-based capabilities, Royal Canadian Air Force (RCAF) doctrine makes only fleeting references to the effects, operations and basic principles of space. It was not until about a year ago, in June 2017, that an advance copy of a space power doctrine note was published in an electronic format only. Currently, the RCAF falls short of some of its closest allies (e.g., the United States, United Kingdom and Australia) in that it has not yet produced its own robust, stand-alone space doctrine, thus inadequately recognizing space as a significant force

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multiplier. To ensure the RCAF remains credible and relevant, space-based capabilities must not only be harnessed, but incorporated into air operations. By introducing space-based data into the Combined Aerospace Operations Centre (CAOC), and by disseminating this data to airborne platforms, operational capability will improve both at home and abroad.

Various command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) space-based assets can be used by the RCAF to enhance operational capability. Satellites can be used for missile warning, environmental monitoring, satellite communications, positioning, navigating, timing as well as intelligence, surveillance and reconnaissance (ISR). The most recent Canadian defence policy, Strong, Secure, Engaged, states that the Canadian Armed Forces (CAF) will acquire nextgeneration "space-based surveillance assets to significantly expand its joint ISR capability." Such capability "will be integrated with existing

assets into a networked, joint system-of-systems that will enable the real-time flow of information that is so essential to operational success." As such, the RCAF is presently looking into developing and/or contributing to the following satellite capabilities: RADARSAT (for highly accurate Arctic surveillance), multi-satellite Arctic communications constellations, and United States Wideband Global SATCOM satellite (to increase access to secure global communications).8

Arguably, the greatest advantage of the aforementioned space-based assets is the ability to operate more than 100 kilometres above the Earth's surface, providing the ability for unimpeded coverage of denied territory. Contrarily, such space-based assets are sensitive to weather and their schedules can be predictable. With anticipated orbits, space-based assets are vulnerable to denial and deception practices, including the controlling of when assets emit and the camouflaging



Designed to operate for seven years, RADARSAT-2 features state-of-the-art synthetic aperture radar (SAR) technology, and supports all the existing RADARSAT-1 beam modes while offering many powerful new capabilities.

Photo: Maxar Technologies Ltd.

of assets. 11 Also, depending on weather patterns, too much cloud cover may impede a satellite's ability to "see" what is happening on the ground. Space-based assets are also very costly and hard to access when repairs are required. 12

In addition to harnessing various C4ISR capabilities, the RCAF must also look at changes that can be made to better incorporate space-based data into air operations, such as introducing a space-operations component into the CAOC. Presently, there are no space subject matter experts (SMEs) physically located in the CAOC. As such, the CAOC must reach back to the Canadian Space Operations Centre (CANSpOC) when space-enabling support is required during the air tasking cycle. Due to the physical separation between the CAOC (located in Winnipeg) and the CANSpOC (located in Ottawa), there are inherent delays in the passage of information. Lack delays could possibly slow the mission-planning process and/or allow mission planning to proceed without all of the essential information available.

By introducing a senior space advisor to the joint force air component commander (JFACC) in the CAOC, a broad set of space expertise could quickly be provided to advise on the planning, executing and assessing of space operations.<sup>15</sup> In the United States Air Force (USAF), the aforementioned senior space advisor is known as the director of space forces (DIRSPACEFOR). The DIRSPACEFOR ensures "that space is integrated into all parts of the operational planning process for the entire joint force ... [and that] SMEs are clearly identified and assigned throughout the [CAOC], both friendly space capabilities and adversary space threats are understood and given

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the proper consideration when planning and conducting operations." <sup>16</sup> Although CAF has a space component commander (SCC), the SCC currently falls under the operational command of the Canadian Joint Operations Command, not the JFACC. By integrating a senior space advisor as well as various space SMEs into the CAOC, the JFACC would have increased SA and would, therefore, have more information upon which to base decisions and prioritization.

It is important to note that the RCAF cannot simply adopt an American-based model as this is neither realistic nor responsible given the differences in force size and responsibilities;17 however, this is not to say that the current Canadian construct cannot be slightly reshaped to adopt aspects of the USAF model for RCAF use. We have already started to see such adaptation. For example, the United States Combined Space Operations Center falls under the command of USAF.<sup>18</sup> Until very recently, CANSpOC fell under the command of the Vice Chief of the Defence Staff; 19 however, CANSPOC now falls under the RCAF. Although space has been mentioned in various RCAF air and space doctrine publications for

years, CAF's primary space-based organization did not fall under the command of the RCAF until early 2018. Of note, CANSpOC remains physically imbedded in the Canadian Joint Operations Command. Without direct command and control over CANSpOC, the RCAF cannot ensure that the existing space-based resources available are providing support to the CAOC if and/or when required, as there are only so many space-based resources which are to be shared among the three environments. Bringing CANSpOC under the command of the RCAF and incorporating military space professionals into the CAOC effectively enables the Commander RCAF to incorporate space with air operations. Although CANSpOC falls under the command of the RCAF, space power would be best delivered under the tenet of centralized control so as to ensure that, in addition to the RCAF, the Canadian Army, Royal Canadian Navy as well as special operations forces all benefit from the space domain.

Once changes are successfully made to integrate space-based support into the CAOC, disseminating space data to airborne platforms would greatly improve operations both at home and abroad. The passage of space-based information directly from the CAOC to airborne platforms would allow for quicker reaction times, allowing for greater probabilities of success concerning domestic search-and-rescue missions and/or kinetic operations overseas, to name a couple of examples. Additionally, space-based intelligence could directly cue airborne platforms to collect detailed information on various targets of interest. Domestically, space data could be disseminated to airborne platforms to improve operations by: "a. monitoring and identifying vessels of interest in Canadian waters; b. monitoring fishing activity within or near Canadian waters; c. monitoring foreign economic

activity within or near Canadian waters; and d. surveying Canadian sovereign territory and approaches for illegal or suspicious activity."<sup>22</sup> Having the ability to disseminate space-based information directly to airborne platforms regarding any and/or all of the above-mentioned activities would improve operational capability. The more information the crew members on-board airborne platforms have while conducting domestic surveillance missions (e.g., illegal fishing activities, drug smuggling), the more chance there is of quickly and successfully identifying illegal activity. Once such activities are identified, then the appropriate steps can be taken to put a halt to the illicit actions.

Concerning overseas operations, such as kinetic-based missions, spaced-based capabilities including synthetic aperture radar satellite reconnaissance and surveillance<sup>23</sup> can greatly enhance a fighter pilot's SA while airborne. Such space data disseminated to an airborne platform can quickly provide additional information on a specific target or target area (e.g., pattern of life, presence of non-combatants). When tasked with a strike mission, it is essential that a fighter pilot has all of the available information and data to ensure that the target they strike is legitimate. The potential political ramifications and other innumerable consequences (e.g., impact on emotional/mental well-being, loss of job) of striking a non-legitimate target are too great.

In conclusion, there are a variety of space-based capabilities which can (and should) be harnessed by the RCAF to not only enable but enhance air operational effectiveness. Satellite systems can be used for communications, navigation and ISR—among other things. Although satellites have the distinct advantage of providing wide coverage and having unimpeded views of denied territory, their sensitivity to inclement weather as well as denial and deception techniques must always be taken into consideration. To ensure that the information made available via space-based C4ISR assets is effectively used, space data must regularly find its way into the air tasking cycle at the CAOC. To accomplish this, space SMEs should be physically collocated in Winnipeg along with the rest of the planning staff. The introduction of a senior space advisor to the JFACC, such as a DIRSPACEFOR or SCC, should be considered. The presence of space SMEs within the CAOC would help to ensure that space-based collected data is received by airborne platforms, enhancing SA of the operators in a timely fashion. With increased SA, operators would be able to make more informed decisions—possibly in life-threatening scenarios.

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#### **ABBREVIATIONS**

**C4ISR** command, control, communications, computers, intelligence, surveillance

and reconnaissance

**CAF** Canadian Armed Forces

**CANSPOC** Canadian Space Operations Centre **CAOC** Combined Aerospace Operations Centre

**DIRSPACEFOR** director of space forces

**DND** Department of National Defence

**ISR** intelligence, surveillance and reconnaissance

**JFACC** joint force air component commander

RCAF Royal Canadian Air Force
SA situational awareness

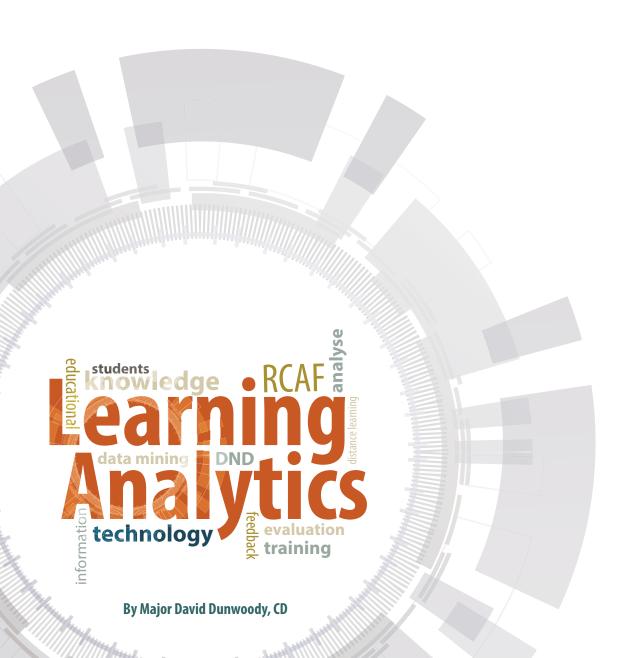
**SCC** Space Component Commander

**SME** subject matter expert

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the Royal Canadian Air Force (RCAF). The Flight Instructor's Course Handbook recognizes this in the first paragraph: "One of the most important jobs in the [Canadian Armed Forces (CAF)] is training. This fact is apparent when it is realized that approximately one-quarter of all personnel in the [CAF] are engaged in some kind of training at any given time. The increasing and varied demands on the military and rapidly changing technology make teaching a fundamental activity."

"The CAF needs to follow through with modern, world-class training that will put new recruits on a solid foundation to succeed."



Grob Flight Commander, Captain Eric Martinat, welcomes a new group of students to the Southport Aerospace Centre in Portage la Prairie, Manitoba, on October 10, 2013.

The Department of National Defence (DND) captured the importance of training in the 2017 Strong, Secure, Engaged: Canada's Defence Policy, which states: "The CAF needs to follow through with modern, world-class training that will put new recruits on a solid foundation to succeed." The RCAF also understands the importance of training through force generation. The B-GA-400-000/FP-001, Royal Canadian Air Force Doctrine, states that "force generation involves an extensive range of activities including recruiting, training, educating, and retaining the right personnel. These activities are essential to the readiness of a competent force with the ability to execute all air power missions." 3

Many members of the RCAF take pride in their roles as instructors, educators and trainers (henceforth referred to collectively as instructors). Their goal is to generate "an agile, well-educated, flexible, diverse, and combat ready military." Their professionalism and dedication are evident in the quality of training seen throughout the RCAF. These professionals strive to deliver the best training possible and are always seeking to improve upon the educational product. For them, good is never good enough. The challenge is to determine where to focus limited resources to improve training.

Through the learning portal of the Defence
Learning Network (DLN), units and organizations
are able to reach a wide audience of students at the
convenience of each student's schedule.

Training in the RCAF continues to embrace technologies and look for innovative ways of delivery. Distance learning (DL) or distance education courses and programmes continue to grow in the RCAF. By eliminating the requirement for a physical presence and fixed timings, DL offers flexibility and open learning. Through the learning portal of the Defence Learning Network (DLN), units and organizations are able to reach a wide audience of students at the convenience of each student's schedule. The DLN is an online tool for managing, developing and delivering training with a focus on continuous learning and sharing knowledge.<sup>5</sup> A challenge with DL courses is assessing the effectiveness of the delivery of the material and the level of participation of the student.

The field of learning analytics seeks to identify the effectiveness of a course's instruction and education. It strives to identify where and how to optimize and improve training through course materials, delivery and student participation. Learning analytics introduces data-mining techniques, qualitative and quantitative analysis as well as tools to provide instructors with the knowledge and wisdom to improve training.

### **Learning Analytics**

As professionals, instructors should always seek to improve in their duties. It is not about fixing what is broken but finding ways to make what works work better. Training units throughout the RCAF do an outstanding job, as evidenced by the quality of aircraft technicians, aircrew, engineers and aviators who ensure the RCAF meets the directed mandates of training, support and operations. This is important to acknowledge as often the focus is on addressing problems instead of improving what already works. This is evident in the wording of several passages in the Canadian Forces Individual Training and Education System (CFITES). Volume 8 of the CFITES manual, "Validation of Instructional Programmes," states that the aim of validating instructional programmes is to "identify any significant instances of ineffective instructions in order to correct them." Volume 11, "Evaluation of Instructional Programmes," states that an evaluation "may be conducted at any time in response to negative feedback. and "focus on a particular area of concern." The focus, therefore, becomes on below-standard instruction instead of programmes that deliver quality instruction and meet the standard.

CFITES does provide direction for learning analytics. Volume 11 describes Kilpatrick's Evaluation Model.<sup>9</sup> This model describes four levels of evaluation:

- 1. Level 1 (Reaction) reports how learners react to the instructional programme;
- 2. Level 2 (Learning) confirms what learners learned;
- 3. Level 3 (Behaviour) confirms that what was learned is applied to the job; and
- 4. Level 4 (Results) confirms that the application of what was learned achieves results in the organization.

These levels describe the steps to evaluate a programme but not how. Volume 11, Supplement 1, "Evaluation and Validation Techniques," discusses methods to collect, analyse and determine findings from the data. <sup>10</sup> Many of the methods to collect data use means that have been in practice for years, including course critiques, interviews and direct feedback. The analysis focuses on the use of

the statistics, coding of data and graphics. While these methods are useful, they do not take advantage of the modern methods for qualitative and quantitative data analysis used in learning analytics.

Learning analytics is the "measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." This definition focuses on the gathering of data, the learner and the learning environment. The definition does not focus on problems or issues and instead focuses on improving learning. There are two important parts of this definition: "optimising learning" and "the environment."

Optimising learning focuses on improving how well a student learns the material. This analysis is done as the student learns, not after. One of the great disadvantages with learning is that instructors confirm a student is struggling after administering a written or practical examination. While many instructors are able to identify potential issues, examinations provide the confirmation needed to take actions. The major problem with this approach is that at this stage the student already has an academic down check against them. The air combat system officer (ACSO) qualification standard defines academic course failure as the failure of a supplemental examination, failure of a supplemental progress test or failure of any combination of three progress tests and final exams. Based on the criteria of three exams, when a student fails, they now have a failure against them. If an instructor can identify and address issues prior to an exam, the student is in a better position to pass and avoid failures that bring them closer to course failure. To accomplish this, learning analytics collects and analyses the data concerning a learner's background, behaviour and progress. The property of the progress of

The environment identifies the goal of improving how instructors deliver instructions. Learning analytics discovers patterns and areas where an instructional institute can make changes to improve learning. Institutes that use DL can identify a student's level of involvement by when they access the online content. This can provide insight if a student's unit is giving them time to work on assignments during working hours or if they must do the majority of work after hours.

Learning analytics is a process that belongs to the discipline of educational data mining. Educational data mining does not differ from data mining, only that the application is towards educational data. The term "data mining" is misleading because it implies the search and extraction of data. Jiawei Han, Micheline Kamber and Jian Pei define data mining as the "process of discovering interesting patterns and knowledge from large amounts of data." The term "knowledge discovery in data" is a popular and possibly more accurate term for data mining. However, many people continue to use the term data mining to reflect the essential step in the process of knowledge discovery; therefore, this article will continue to use data mining.

Figure 1, the Data-Information-Knowledge-Wisdom (DIKW) pyramid, captures the evolution of data when placed through the data-mining process. The descriptions for each level of the pyramid are as follows: <sup>15</sup>

- 1. Data is the discrete fact obtained from the results of exams, course feedbacks and student files. These facts do not have meaning. An exam result of 55 is only a number until the learning institute turns it into information.
- 2. Information is data that has meaning. It answers the questions what, where, when and who. Applied to the exam result, the learning institute states that it is for the Air

Regulations exam written by Second Lieutenant (2Lt) Smith and the pass mark is 70%. They now have meaning with the data and the information shows them that 2Lt Smith failed the Air Regulations exam.

- 3. Knowledge is information that has been processed to show us patterns, relationships and interactions. Knowledge answers the questions why and how. Collecting the information of 2Lt Smith's previous exams, the learning institute finds that the 2Lt has passed all exams to this point. As the learning institute gathers more information, they find that there is a pattern among other students failing this subject while doing well on others. Furthermore, the information shows that the Air Regulations exam was recently modified. This provides the "why," that the changes in the exam may not have reflected the course material taught.
- 4. Wisdom is the use of knowledge to solve problems and make decisions. The learning institute can make the decision to re-evaluate the Air Regulations exam material and ensure it is in line with the course material taught.

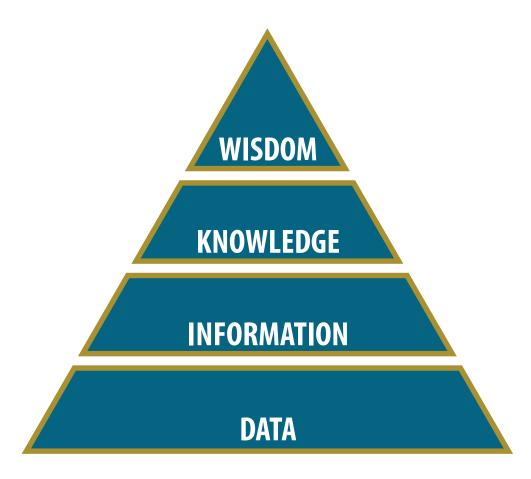


Figure 1. DIKW Pyramid

Data mining uses seven steps to go from data to knowledge on the DIKW. Wisdom is not part of the data-mining process, as it involves the human user making the decision on how to act on the knowledge discovered through data mining. The seven steps are:<sup>16</sup>

- Data cleaning The removal of noise and inconsistent data. Noise may be corrupted
  data. Inconsistent data represents data that falls outside of the norm and represents an
  abnormality. For example, if one student was sick and missed an exam, a mark of 0% may
  have accidentally been entered into the system. This mark would skew the course mean
  and not represent a correct sample.
- 2. Data integration Combining multiple data sources into one. The results of exams may be combined with data from the Member Personnel Record Résumé (MPRR).
- 3. Data selection Retrieving relevant data for the analysis. Data mining does not require all the data for the analysis. An MPRR contains a large amount of information, including occupational history, honours and awards as well as qualifications. An analysis will likely not require the data of the student's last FORCE [Fitness for Operational Requirements of Canadian Armed Forces Employment] fitness test.
- 4. Data transformation Transforming and consolidating data into forms appropriate for mining. Transforming grades into ranges of 5% groups (70%–74%, 75%–80%, etc.) can produce results that are more meaningful. Another example, changing a naval rank from lieutenant(N) [Navy] to captain, ensures the analysis compares the same ranks.
- 5. Data mining This step extracts patterns. The analysis uses methods and algorithms such as clustering and classification to find patterns in the data.
- 6. Pattern evaluation The user identifies the truly interesting patterns. Not all patterns will be of value. This stage finds those that will transform information into knowledge in the next step.
- 7. Knowledge presentation Presenting the mined data to users using visualizations. This is the final stage where the user has the knowledge to proceed to the final step of wisdom and make the decisions.

To accomplish the data-mining process, a large number of tools exist to collect, track and analyse the data to effect decision making in learning institutes.

### **Tools**

Course management systems (CMSs), also known as learning management systems (LMSs), refer to software tools that enable educational institutes to develop, deliver and monitor courses between the instructors and students. Common features of CMS are the ability to distribute information to students, produce content material, prepare assignments and tests, engage in discussions, manage distance classes and enable collaborative learning through forums, chats and file storage areas. There are several commercially available CMSs: Blackboard, Adobe Captivate Prime and TalentLMS as well as free CMSs: ILIAS, Claroline Connect and Moodle. In addition to facilitating instruction, many CMSs enable learning analytics through data collection and integration with third-party tools.



One of the best CMS tools is Moodle. Moodle is a flexible and powerful tool in use worldwide. Through Moodle, instructors are able to create personalized learning environments for both online and blended (online and in-house) courses. The tool is scalable to any size, from a few students to thousands of users. Moodle is continually being updated to maintain data security and user privacy. Finally, Moodle is an open-source, free tool.<sup>24</sup> It is currently in use by over 90,000 educational institutes, manages over 15,000,000 courses and has over 125,000,000 users.<sup>25</sup> Moodle provides more tools and data than the DLN and is in use by the Royal Military College of Canada and the Canadian Forces College.

Moodle keeps detailed logs for further analysis. It logs every click that a student makes for navigation purposes, elapsed times for responses, exam marks as well as login times and dates. In addition, Moodle logs group activities and discussions. It captures the amount of time on certain activities and the level of completion of tasks and assignments. Unfortunately, instructors and administrators cannot easily interpret this data. Moodle stores the data in the form of relational databases (e.g., Microsoft Access) containing approximately 145 interrelated tables. <sup>26</sup> To transform Moodle data into information and knowledge requires data-mining tools.

There are many data-mining tools available, both free and commercial, to analyse data. One of the most common and popular tools is Microsoft Excel, which contains a suite of statistical-analysis tools as well as graphs to present the information visually, providing more pertinent data to consider during the decision-making process. Another data-mining tool is the free Weka.<sup>27</sup> Weka is data-mining software that provides a large number of algorithms for clustering, classification, and association data mining. Weka users are able to define the parameters of algorithms such as neural networks or Naïve Bayesian Classification to identify patterns in the data. These tools allow for quantitative data analysis dealing with numbers. They do not allow for qualitative data analysis.

Qualitative data analysis is the analysis of non-numeric information such as text documents, videos, and audio recordings.<sup>28</sup> Qualitative data analysis can identify the predominant theme of an essay, the strength of relationships between key words and phrases as well as the emotional

Qualitative data analysis can identify the predominant theme of an essay, the strength of relationships between key words and phrases as well as the emotional content of a document.

content of a document. As with the previous tools, there is a variety of commercial and free tools available. QDA [Qualitative Data Analysis] Miner from Provalis Research is a commercial product that can carry out qualitative analysis of text, pictures or speeches.<sup>29</sup> IBM's Watson Natural Language Understanding analyses text for emotional content. It determines the probability of anger, sadness, joy, confidence or tentative emotions, among others, in a document.<sup>30</sup> Instructors can use this tool to assess the emotional tone of an essay or identify if the course critiques are generally positive or negative.

Semantic Knowledge's Tropes is a free text and semantics qualitative analysis tool.<sup>31</sup> It can group words and phrases into scenarios, such as grouping fighting, offensive, defensive, engagement and battles under the scenario of war. Tropes will show the relationship between words and show which words they influence. It is able to analyse up to 10,000 files and 10,000,000 words.

Gephi is an open-source visualization, analysis and exploration platform.<sup>32</sup> It can display the strength and direction of the relationships of key terms from Tropes. It can filter and cluster the results of an analysis and allow users to manipulate the information to highlight critical patterns for knowledge discovery.

Both Tropes and Gephi require training to exploit the full capabilities. Once a learning institute creates the scenarios and templates, it can reuse them for every course. Analysis can be on group discussions, course critiques, and essays. This enables instructors to see what common themes the students are generating and if the students are meeting the objectives of the course. Additionally, instructors can use the results to identify areas to improve or any issues not easily identified.

One disadvantage with these tools is that they do not directly interface with Moodle. Given the popularity and the amount of data available from Moodle, there is an incredible wealth of knowledge and wisdom available and a need to access that data. GISMO [Graphical Interactive Student Monitoring] is a free software that can provide instructors with the means to analyse Moodle data.

GISMO is a graphical interactive monitoring tool that provides graphs on students' online activities.<sup>33</sup> It can display the level of participation, attendance, submission of assignments and exam results. Furthermore, it can provide a view of the entire class or an individual student. Figure 2 is a graph of when students accessed the course. The instructor can select individual students and examine all the way down to how many times the student accessed the course and the time of day. This information can help an instructor to determine the level of participation of the student, such as whether the student accessed a discussion forum daily or waited until the last day to participate. This graph shows which students have been actively participating and which ones have not accessed the course. Following that, Figure 3 shows the results of the students' assignments. The squares with a red outline or a red box represent students who completed the assignment. The shade of the box shows the overall results (the darker the shade, the better the results). An empty box with a red outline means the instructor has not graded the assignment. This graph shows that four students have not done any assignments and no one has completed the last assignment.

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Figure 2. GISMO Students: accessed by students<sup>34</sup>

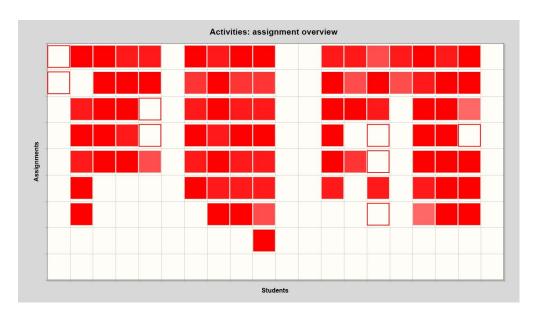


Figure 3. GISMO Activities: assignments overview<sup>35</sup>

Moodle is configurable from a few students to thousands per course. GISMO allows visualization of hundreds of students to allow instructors to find patterns. Furthermore, this tool enables administrators, supervisors, and standards to find patterns, identify issues and assess the quality of instruction.

### **Advanced Analysis Methods Examples**

In data mining, there exists a large number of algorithms and tools to enable users to extract and discover information and knowledge beyond the capabilities of Microsoft Excel and simpler tools. The advantage of these tools is that they are capable of discovering knowledge that is normally impossible, extremely difficult or time consuming to find. Furthermore, they can do so quickly. The disadvantage is that, in many cases, these tools require training and data-mining knowledge to make them effective. The methods discussed next are classification and qualitative data. These methods highlight some of the more advanced learning analytics techniques.

Classification is a model that predicts the categorical class label based on given data.<sup>36</sup> Given a loan applicant's personal and financial history (data), a bank is able to predict if the client is a safe or high risk (category). In education, this model can predict if a student will pass or fail a course based on their first few tests, which can be beneficial for a learning institute to identify early which student requires extra help. Three common methods are Naïve Bayesian Classification, decision trees and neural networks.

The key to the success of the method is the use of historical data. The classification models use historical data in order to "learn" the probability that a student belongs to a specific category. To learn, the methods require two sets of data. The first is the student data. This includes a student's marks, positive or negative reports as well as other data that may be relevant to the student's performance. The second set is the class labels for the category, which gives the historical results of the final marks of each student.

Naïve Bayesian Classification is comparable in performance to decision trees and neural networks. Furthermore, it shows high accuracy and speed even on large databases.<sup>37</sup> The following example uses a set of fictitious data to demonstrate how classification work. Table 1 is the historical data of 10 students. It shows their results in their first two exams and whether they passed or failed the course. If a new student scored 78% on the first exam and 83% on the second exam, the method computes the probability of passing or failing. In this situation, the probability of passing is 0.0555 and the probability of failing is 0.0625.<sup>38</sup> Thus, the student has a higher probability of failing. Instructors now have the knowledge to make a decision (wisdom) on whether or how to intervene.

Student	1st Exam	2 <sup>nd</sup> Exam	Final Standing
Student A	91–100%	81–90%	Pass
Student B	81–90%	81–90%	Pass
Student C	81–90%	91–100%	Pass
Student D	71–80%	81–90%	Pass
Student E	81–90%	71–80%	Fail
Student F	71–80%	61–70%	Fail
Student G	91–100%	61–70%	Pass
Student H	61–70%	81–90%	Pass
Student I	61–70%	81–90%	Fail
Student J	<= 60%	61–70%	Fail

Table 1. Historical student marks for Naïve Bayesian Classification

Learning Analytics can apply to the performance of instructors as well as students. Examining an instructor's assessment on students can show standards if the instructor is assessing the correct items to determine if a student has met the performance objective or if the instructor is focusing on the wrong details.

In the analysis, it is important to discretize the data in order to improve categorization. To discretize refers to placing values into groups (e.g., 87% into the 81–90% exam score label). This improves the results of the analysis by reducing the possible outcome. Discretization can further apply to the final standing. Instead of pass or fail, the classification can determine the range of marks for the student. Determining the fidelity of the discretization can be difficult and requires knowledge and experience from data mining.

It should be evident that the more historical data available, the better the model "learns" how to categorize the data. This can be a challenge as courses evolve and change. The exam given to a student in 2018 may be very different from the one given in 2008. Despite this, classification methods have shown to enable knowledge discovery in commercial and research applications.

Qualitative data analysis is the analysis of non-numeric information.<sup>39</sup> A common use of this analysis method is to find patterns in texts such as reports, group discussions and the narrative of instructors' assessments. Semantic Knowledge's Tropes and Provalis Research's QDA Miner are two tools capable of qualitative data analysis. Gephi is a powerful visualization tool capable of allowing users to explore the relationship of qualitative data.

Learning analytics can apply to the performance of instructors as well as students. Examining an instructor's assessment on students can show standards if the instructor is assessing the correct items to determine if a student has met the performance objective or if the instructor is focusing on the wrong details. 402 Squadron at 17 Wing Winnipeg trains ab initio ACSO students. The assessment forms include a numerical rating for each enabling objective. Additionally, they contain a narrative section stating the observations by the instructor that justify the rating.

A qualitative data analysis was carried out on the narrative section of several dozen assessments. Prior to the analysis, the students' personal information was removed from the narrative. Tropes analysed the text for relations between words and Gephi created a graphical representation of the analysis, shown in Figure 4, which indicates that the narrative text had strong associations between many terms. The largest relationship is "flight" and "phases," showing that the assessments observed often how the students dealt with the phases of flight. The terms "fuel" and "calculation" also have a strong association, most likely because of the importance of the students to do correct fuel calculations. Using this graphical view, standards can determine if an instructor is focusing on important points for flights.

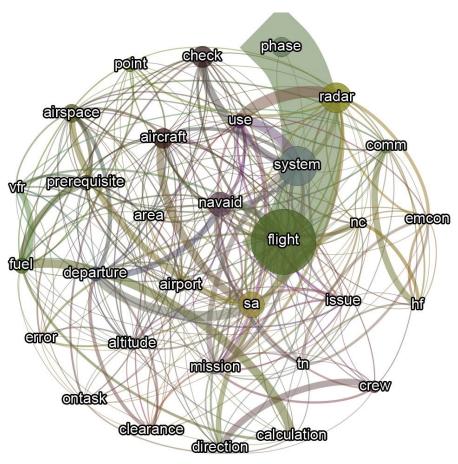


Figure 4. Qualitative data analysis of assessment form narrative

### **Summary**

Learning analytics is "the measurement, collection, analysis, and reporting of data from learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." It seeks to identify the effectiveness of courses, with the goal of improving learning through course materials, delivery, and student participation and success. Learning analytics is a

discipline of data mining or knowledge discovery in data. Data mining comprises seven steps: data cleaning, data integration, data selection, data transformation, data mining, pattern evaluation and knowledge presentation. The goal is to transform raw data into a decision.

The DIKW pyramid is the process of turning data into a decision. Data is the discrete fact. Information is data that has meaning. Knowledge is the pattern, relationship or interaction found in the information. Finally, wisdom is the use of the knowledge to solve problems, determine improvements, and make decisions. Data mining can automate the first three steps. The final step, wisdom, is the done by the instructor with the knowledge gained.

Learning analytics uses the tools CMS or LMS. There are many commercial or free tools. One of the most widely used is Moodle, a free CMS currently used by over 90,000 educational institutes. Moodle keeps detailed logs of every click a student makes for navigating pages, elapsed times for responses, exam marks as well as login times and dates. Moodle stores this data in tables. GISMO is a graphical interactive tool that allows users to see visuals of the data stored in the Moodle tables.

Qualitative data analytics analyses non-numerical data, such as texts and audio, for the strength of relationships and influence between words and concepts. Semantic Knowledge's Tropes is a free text and semantics qualitative analysis program that can analyse large text documents for words and phrases. Gephi is a powerful visualization platform that provides a graphical representation of the qualitative relationship of text documents.

Affective analytics identifies emotions and sentiments in documents. While emotions are specific (fear, happiness, sadness, joy), sentiment states if a document was positive, negative or neutral in emotion. IBM's Watson Natural Language Understanding analyses text for specific tones and sentiment.

An analysis of course work and performance provides instructors with a large amount of know-ledge. Advanced methods can predict future performance, thereby allowing instructors to intervene early. The analysis is not restricted to a single course but can assess patterns over years' worth of data to allow instructors to see patterns over time.

### **Conclusion**

As professionals, instructors are always seeking ways to improve the learning experience. Good is never good enough. As the RCAF explores new ways of delivering material through distance education and computer-based learning, new tools and methods are needed to find patterns and enable instructors to make the best decisions with the limited resources available. Learning analytics provides the means to bring learning into the 21st century.

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### **ABBREVIATIONS**

**2Lt** second lieutenant

ACSO air combat system officer
CAF Canadian Armed Forces

**CFITES** Canadian Forces Individual Training and Education System

**CMS** course management systems

**DIKW** Data-Information-Knowledge-Wisdom

**DL** distance learning

**DLN** Defence Learning Network

DND Department of National Defence
LMS learning management systems

**RCAF** Royal Canadian Air Force

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A WAY FOR CANADA TO DISTINGUISH ITSELF INTERNATIONALLY

BY MAJOR MARTIN VOYER, CD, MOS



ARMED DRONES REPRESENT A

STRATEGIC, OPERATIONAL AND

TACTICAL ADVANTAGE FOR CANADA.

THEIR POTENTIAL JUST NEEDS TO BE

UNDERSTOOD AND EXPLOITED.

**Editor's note:** This paper was written by a student attending the Canadian Forces College in fulfilment of one of the requirements of the course of studies.

### INTRODUCTION

When Carl von Clausewitz wrote *On War*, he could never have anticipated that, with the invention of the airplane, the sky and the ground would become so closely tied when waging war. With all the possibilities and benefits that flight may involve, it would henceforth be shaped by the third dimension. Clausewitz writes that the feeling of power can be expressed with three words: dominating, commanding and overlooking; "from these sources springs the sense of superiority and security which is felt in standing on the brow of a hill and looking at the enemy below, and the feeling of weakness and apprehension which pervades the minds of those below." Although Clausewitz refers to standing on the high ground in his work, it is still possible to draw a parallel with the use of aircraft and drones in modern armed conflicts. The use of air resources, more specifically armed drones in the context of this paper, makes it possible to dominate, command and overlook the enemy fighting in a complex environment. The purpose of this paper is not to debate whether Canada should obtain armed drones, but rather to show that the use of armed drones would facilitate the targeting process and would therefore allow Canada to distinguish itself as being more independent internationally.

This work will consist of three parts. First, we will look at armed drones and the reasons why it would be preferable to use them instead of fighter aircraft. This part will therefore focus on drone capabilities. It should be noted that this is not an argument in favour of any particular platform. However, we will examine various models used by other countries, in particular the United States and Britain. We will discuss the various advantages of using drones, such as cost reduction, operational distance separating the pilot from the conflict zone and increased autonomy in a non-permissive environment.

The second part will review the capabilities of armed drones in the targeting process and look at how they facilitate and accelerate the process. To do this, two doctrines will be explored in greater depth: the United States' joint targeting doctrine and Canada's joint targeting doctrine. The Canadian process and the North Atlantic Treaty Organization (NATO) process are greatly influenced by the American process, but given that the purpose of this work is to demonstrate that Canada could act more independently on the international stage, it is appropriate to look at



An MQ-9 Reaper taxis after a mission in Afghanistan.

Photo: United States Air Force

our own doctrine. There are two types of targeting processes: deliberate targeting and dynamic targeting. The use of armed drones will be assessed based on these two types of targeting, but more attention will be paid to dynamic targeting, in which time and space are critical factors.

The last part of the work will address Canada's international role. It will be shown that procuring armed drones and integrating them into a complete targeting process would enable Canada to be more independent when participating in international and regional missions. Morality, legality and deterrence will be addressed and explained based on the various mission types that Canada is required to conduct. Armed drones represent a strategic, operational and tactical advantage for Canada. Their potential just needs to be understood and exploited.

### ARMED DRONES: CAPABILITY

Operational theatres are growing in complexity and scale. Therefore, we must adapt the resources used, just as those who use them must adapt. Irregular warfare in unstable countries is an ideal use case for armed drones. Armed drones will never replace fighter aircraft. However, the author is of the opinion that these drones are an indispensable complement to fighter aircraft. "Victory is not possible without persistent ISR [intelligence, reconnaissance and surveillance] and combat air patrol. ... It is virtually impossible to engage in unconventional operations without holding the big stick of deterrence and without controlling the thin air." As previously mentioned, the primary advantages are associated with costs, the distance separating the pilot from the conflict (i.e., the safety distance) and the increased autonomy in hostile environments.

A very interesting point in favour of armed drones is that the procurement, maintenance and operating costs are lower than the costs for a new-generation fighter squadron. For comparison purposes, we will use the costs of the various models of F-35 Joint Strike Fighter, as well as the costs of the MQ-1C Gray Eagle and MQ-9 Reaper. In terms of procurement, the prices of the different variants of F-35 range from US\$102.1 to \$132.2 million per aircraft.3 For armed drones, the Gray Eagle sells for US\$6.66 million, while the Reaper sells for US\$14.75 million.<sup>4</sup> The armed drone costs do not include the control stations and other related equipment, just the aircraft. The annual cost to operate and maintain a Reaper in 2008 was US\$5.43 million, and an MQ-1 cost US\$1.33 million. This enabled the United States (US) Department of Defense (DoD) to assess the average cost per flight hour of the MQ-9 Reaper at US\$3,538.5 For the F-35, the estimated cost per flight hour is approximately \$32,000.6 Regardless of the numbers used here, some will say that it is unfair to compare two different platform types, but it would be a mistake to think that way. Indeed, even though two different platforms are being compared, they are expected to perform the same duties. It could be asked why we should pay \$32,000 per hour to execute ISR missions with an F-35 when the Reaper can do it for a little more than one tenth of the cost. Why not use armed drones when air superiority is unchallenged?



General Atomics MQ-1C Gray Eagle.

Photo: General Atomics

The distance from which the pilots conduct their missions is another significant advantage directly related to protecting human capital. With 24/7 live news, people around the world witness conflict and experience it in a virtually real way through the media. This virtual proximity of the theatre of operations allows people to take ownership of war in their own manner. People demand accountability from their government when they are not satisfied with the way operations are going or when they are concerned about the protection of non-combatants. This demand for transparency means that governments are increasingly risk-averse, particularly when risking loss of human life. Using armed drones opens up two possibilities: when air cover from drones is constant, ground troops are more secure, and drones do not endanger a pilot's life.

Even though fighters are also perfectly capable of providing close air support to protect ground troops, the situation and environment in which pilots carry out their missions remain sources of intense stress. Despite the minimal air threat in irregular conflicts, all the stimuli that the pilot receives may lead to pilot error. Remember the incident on 17 April 2002 in Afghanistan: an American F-16 pilot thought he was under attack and struck Canadian troops participating in a night firing exercise near Kandahar. Major Schmidt, who had just conducted a 10-hour night-patrol mission, feared for his life and that of his wingman. "[O]ne of the F-16s invoked the right

HND CLOSE AIR SUPPORT COULD COST A
FRACTION OF THE CURRENT PRICE.

of self-defence and released a Mark 82 500-lb Guided Bomb Unit (GBU-12) laser-guided bomb (LGB) on the soldiers' firing position." This friendly fire resulted in four dead and eight wounded.

Some people might note that armed drone pilots very often suffer from psychological issues associated with their engagements. Scientists have found that the problem is related not so much to the engagements, but to the huge contrast between the different roles pilots perform during a short period of time. At one given moment in the day they are targeting insurgents; the next, they are at their children's soccer game or are grocery shopping with their partner. A simple way to mitigate this contrast would be to deploy these pilots to a location different from that of their daily lives so that their brains can associate the engagements with a specific location. These measures would thereby promote the mental health of drone pilots.

The last advantage that will be addressed in this part is the autonomy of armed drones. Armed drones have an autonomy that far exceeds that of fighter aircraft, as fighter pilots and the crew of other types of ISR aircraft have physical limitations. Even if tanker aircraft allow fighters to stay on station longer, it is impossible to change pilots as can be done with armed drones, whose pilots manoeuvre the aircraft from the ground. The fighter pilot, being human, is therefore constrained by fatigue. Returning to the example of the 2002 friendly-fire incident in Afghanistan, the pilot was returning from a 10-hour night mission. Fatigue may have altered his judgement. In the case of armed drones, pilots also perform long flights, but they are not subject to g-forces or the difficult conditions in the theatre of operations. Returning to the autonomy of armed drones, an MQ-9 Reaper has an endurance of 27 hours. A new extended-range Reaper variant can now fly for 42 hours before having to land.8 This flight time represents a significant advantage for persistent observation. Flight times of different armed drones vary widely based on the number of weapons they carry. This argument is also true for fighters. Since the armed drones are smaller airframes, they can carry fewer weapons. The Predator can carry two Hellfire missiles, while the larger Reaper can carry four, in addition to two 500-lb bombs. Even compared with a standard fighter aircraft, this is still a very significant weapon load, given the size of the armed drones. Extended time on station makes it possible to maintain better situational awareness. This will be discussed in more detail in the use of armed drones in the targeting process.

In this part, it has been shown that cost, operational distance, and autonomy are the main advantages of armed drones. Using armed drones for ISR missions and close air support could cost a fraction of the current price. The distance between the pilot and the aircraft reduces the risk of loss of human life and the risk of self-defence-related and fatigue-related errors. Long-endurance drones would practically allow airspace saturation and therefore permanent air cover over ground troops. The next section will deal with the targeting process and how integrating this new capability could speed up the decision-action cycle.

### TARGETING: THE PROCESS

The targeting process is relatively new in Canada. The first edition of the Canadian Forces Joint Publication (CFJP) on targeting <sup>10</sup> is dated December 12, 2014, and has been greatly influenced by the US manual, dated April 13, 2007. Since armed-drone capabilities are already used in the American targeting cycle, it would be interesting to consider using them to facilitate and accelerate the Canadian targeting process. The use of armed drones does not influence the entire targeting cycle. In fact, this capacity primarily influences the dynamic targeting process for various reasons. Here, we will see that armed drones, through how easily they can engage targets and how long they can stay on station, are ideal for playing a major role in all steps of the dynamic targeting cycle.

The multirole nature of armed drones will in itself make the dynamic targeting cycle faster. We will see that the notions of time and space are essential in this type of targeting.

Whether in the Canadian or American publication, the targeting cycle is made up of six steps:

- 1. end state and commander's objectives;
- 2. target development and prioritization;
- 3. capabilities analysis;
- 4. commander's decision and force allocation;
- 5. mission planning and force execution; and
- 6. assessment.11

Of these six steps, three may be facilitated by the use of armed drones: step 2, target development and prioritization; step 5, mission planning and force execution; and step 6, assessment. We will see that dynamic targeting falls under step 5 of the general targeting process.

EFFECTS, COMBAT AND COLLATERAL
DAMAGE ASSESSMENTS ARE ALL TASKS

WHERE DRONES CAN HELP COMMANDERS

REVIEW THE SITUATION.

As armed drones are, above all, a surveillance, target-acquisition and reconnaissance platform, their role in target development is important. "This intelligence support is vital for the analysis performed in target development, as well as to prepare for future targeting during the execution of operations." Obviously, target development is not done solely by observation using drone sensors. Many intelligence sources are required to support the information collected. However, for a target to be developed, it must first be detected, observed and assessed. These three requirements may be satisfied with armed drones. Other sensors may also establish a target, but drones are practically the only type with the mobility required to follow a mobile target for a very extended period. For example, a special-forces member on a reconnaissance mission may observe enemy facilities and discover insurgents' comings and goings, but as soon as the insurgents leave the gathering point, physical surveillance becomes extremely difficult and risky. However, the long endurance, cruising altitude and stealth of drones make possible not only positive identification of the object, but also

development of civilian activity and the activity profile. Both these notions are critical to determining whether the target engagement is legal.

Before discussing step 5 and dynamic targeting, it would be useful to discuss the contribution of armed drones in step 6 of the process. Drones can also conduct an after-engagement assessment. Effects, combat and collateral-damage assessments are all tasks where drones can help commanders review the situation. Combat assessment is certainly the part of the engagement assessment where armed drones are very well equipped to do the job. With information from their optical, electronic and thermal sensors, we can conduct battle damage assessments (BDA), mission-success assessments, weapon-effectiveness assessments and re-attack recommendations. Such an attack may be risky for fighter pilots, as they are exposed to the enemy who survived the first attack. However, using an armed drone entails no risk to the pilot. Even if the drone is out of weapons, it can still orbit and continue to observe and assess until a new armed drone can take over.

Dynamic targeting, at step 5 of the joint targeting process, is undoubtedly the type of targeting where armed drones really have a major advantage. Dynamic targeting "primarily prosecutes targets of opportunity, which are targets identified too late, or not selected for action in time to be included in deliberate targeting; or planned targets whose status has recently changed necessitating more expedient prosecution." <sup>14</sup> As shown in Figure 1, there are seven steps in the dynamic targeting process.

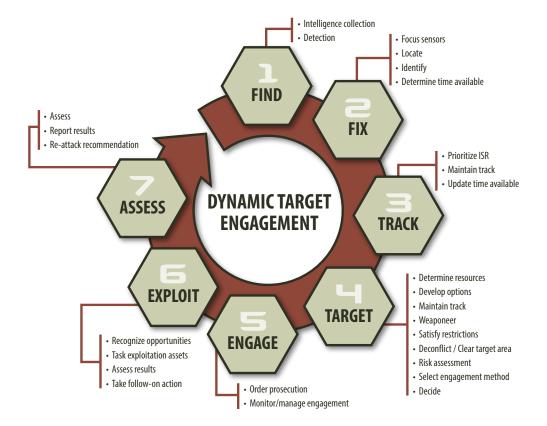


Figure 1. Dynamic targeting process steps<sup>15</sup>

When it comes to targets of opportunity, the targeting cycle must be done very quickly. Otherwise, we risk losing the opportunity to engage the target. It is easy to see that armed drones can carry out all of the above-mentioned steps. Fighter aircraft can also do it, but again, this depends on the situation. The primary role of a fighter is to deliver a bomb to a target. Aircraft are primarily used for the engage step. Everything before and after the engage step is normally done by ISR drones. We must ask ourselves why we need two valuable resources to carry out the full targeting cycle when armed drones can do it by themselves and more quickly. This brings us to the notion of an "urgent target."

Armed drones are ideal for engaging time-sensitive targets (TSTs). A TST is a "target requiring immediate response because it is a highly lucrative, fleeting target of opportunity or it poses (or will soon pose) a significant danger to friendly forces." <sup>16</sup> US doctrine states that "Fleeting TSTs may be difficult to detect or identify because of the adversary's use of mobility and/or denial and deception techniques. Hence the target may need to be rapidly engaged before the adversary can employ mobility and/or denial and deception." <sup>17</sup>

There are three considerations affecting TSTs. Canadian doctrine mentions intelligence, time as well as engagement capabilities and limits. Synchronization between intelligence and ISR resources must be done quickly to optimize intelligence collection and target development. Since time is limited, it is important to properly assess the situation and consider the risk of attacking or doing nothing. The more effective the coordination between the various systems necessary to engage the target, the quicker the engagement will take place. In terms of engagement capabilities or limits, an observation system that can also engage a TST is an advantage. For example, the artillery forward observation officer who observes a TST could engage much more quickly with an artillery battery from their own unit than if this same target had been observed by a reconnaissance detachment from another organization. This is because there is an organic link between the forward observation officer and their howitzer battery. The same parallel can be drawn with armed drones. They have the opportunity to observe and engage TSTs. Therefore, the armed drones' multi-role capability gives them a distinct advantage.

To conclude this section, it is important to review a few notions. Initially, the Canadian targeting process was described. It resembles the American model in many respects. It consists of six steps. Three of them are steps where armed drones can help speed up the targeting process. Step 5, mission planning and execution, includes dynamic targeting and the importance of armed drones. This dynamic targeting mainly consists of TSTs for which we must consider three criteria: intelligence, time as well as engagement capabilities and limits. Armed drones may intervene in all three cases to shorten the targeting cycle. Now that we have determined that the capability is helpful in the process, we must discuss how the process and its capability can change the system.

### CANADA ON THE INTERNATIONAL STAGE: THE SYSTEM

Canada's position in the world gives it an undeniable strategic advantage. Bordered by three oceans and a superpower to the south, Canada benefits from protection against most international problems. This is possible because of geographic isolation and the protective shield provided by the United States. This situation has never allowed Canada to play a leadership role internationally. During its participation in armed conflicts, Canada has assumed a supporting role that has mostly been dictated by American imperatives. Adding armed drones to the Canadian arsenal could enable more flexibility in the role assigned to us and in the choice of possible operations. Consequently, this would ensure Canada has greater independence with respect to the United States. "It is strategic

attack based on precision, stealth aircraft, and standoff weapons which offers extraordinary new options to American political leaders." <sup>18</sup> If American political leaders have this option, why should Canadian political leaders not have the same option, to a lesser degree? An arsenal the size of the Americans' is unnecessary; we just need to create a custom-made capability that suits our national interests and ambitions. Using armed drones internationally would enable three specific things. First, since ISR is their primary role, drones could collect the intelligence necessary to create a target database for Canada only. This would give us "the ability of precision-guided munitions (PGMs) to destroy strategic targets more easily and more rapidly." Still from a strategic point of view, "PGMs make it possible for fewer aircraft [and armed drones] to destroy more targets than in the past."20 This allows for substantial savings. Second, drones could provide enhanced protection for deployed forces during peace enforcement and counter-insurgency (COIN) missions and respond first when troops are attacked. Not having to request resources from another nation would be a massive advantage in this case. Lastly, they would dissuade the irregular enemy or local militia from trying anything to disrupt, injure or destroy the force in place. In theatres with active asymmetrical conflicts, it is often preferable to prevent enemy action rather than to react to it. All strategic success is based on the economy of effort during a lengthy conflict. Canada is preparing to deploy troops to Africa. This theatre of operations could be a good location to begin using Canadian armed drones.



The Sperwer unmanned aerial vehicle (UAV) awaits preparation for its maiden flight in Kabul, Afghanistan.

Photo: Corporal Doug Farmer

Regionally, using armed drones would increase the credibility of Canada's political commitments to NATO and the US. The US is currently criticizing Canada for what it believes to be unsatisfactory efforts in providing material and financial resources to NATO. Canada, with a fleet of armed drones, could easily offset its lack of fighter aircraft on missions to areas where there are irregular conflicts. Not only would Canada's war effort be increased within the alliance, but the security of deployed Canadian soldiers would not be compromised or challenged by public opinion. Armed drones could be a significant asset regionally; that is, we could use them to protect

PROTECTION FOR DEPLOYED FORCES

DURING PEACE ENFORCEMENT AND

COUNTER-INSURGENCY (COIN) MISSIONS

AND RESPOND FIRST WHEN TROOPS

ARE ATTACKED.

North America (NORAD [North American Aerospace Defence]). While armed drones cannot engage fixed-wing or rotary-wing targets, they would be an excellent addition to the Canada-US air forces already protecting North American airspace. NORAD's mission is so described: "The North American Aerospace Defense Command conducts aerospace warning, aerospace control and maritime warning in the defense of North America."21 It is precisely in the last part of the mission that armed drones may be very useful. Armed drones' very high level of autonomy enables them to cover tremendous distances without refuelling. With their radar, optical and thermal sensors, as well as their ability to relay information over long distances, they are very well equipped to patrol the coasts and detect marine activities around the periphery of the North American continent. Armed drones use their weapons to engage suspicious vessels that do not comply with authorities or they can simply conduct low-altitude flights as a sign of deterrence. This would allow the Canadian Armed Forces (CAF) to deploy its fighters primarily to operations requiring the physical presence of pilots, such as air-to-air operations. Armed unmanned aircraft could also be used to defend our sovereignty in Canada's North. With the opening of the Northwest Passage, Canada will need all the methods necessary to deter vessels from sailing in its territorial waters. Armed drones could be the solution to these problems, but regulations limiting their use over Canadian territory will have to be reviewed.

The use of drones by CAF to monitor Canada's population is prohibited except when CAF is mandated to do so. This area is under the jurisdiction of the Royal Canadian Mounted Police (RCMP). The first time CAF used drones for a domestic operation was in 2002 during the G8 Summit in Kananaskis, Alberta. CAF was used in support of the RCMP. The operation was declared a success, and many questions were raised concerning the ethical and legal aspects of collecting information on the Canadian population. "There is a great concern that [unmanned aircraft] applications may collect personal information, intentionally or inadvertently." Internationally, ethical and legal aspects of armed drones are governed by the targeting process. Before each engagement with an armed drone, the target must undergo a deliberate or dynamic targeting process in which the authority to engage targets validates the legality and legitimacy of the engagement. The Canadian government must now amend the laws and regulations to facilitate the use of military drones in Canadian airspace. Perceptions of drones must change. In terms of patrols, there is no difference between a fighter aircraft and a drone overflying Canada. Both have practically the same sensors.

### CONCLUSION

The purpose of this work was to show that adding armed drones to the Canadian arsenal would facilitate and accelerate the targeting process and would allow Canada to distinguish itself in a more independent manner internationally. The approach used has allowed us to discuss the advantages of the new capability of armed drones compared with the pre-existing capability of fighter aircraft. After having demonstrated that drones represented a clear advantage, it was necessary to explain the way in which the targeting process could be facilitated and accelerated by this new capability. Only after describing how this process could be improved were we able to suggest ways in which Canada would improve its international standing. In summary, it was sufficient to demonstrate that improving a process by adding a new capability begins to improve a system. To confirm that this is the case, the various parts of this document must be reviewed.

In the first part, comparing fighter aircraft and armed drones demonstrated that armed drones were the most efficient resource in an environment where friendly forces had air superiority or supremacy. Drones are more efficient for three main reasons. First, they cost only a little more than one tenth of the price to do the same jobs as fighter aircraft; namely, ISR and close air support. Second, drones protect pilots who operate them from a distance. The fact that no life is threatened during the mission allows for a decrease in errors in judgement caused by difficult and dangerous conditions. Lastly, drones' high level of autonomy enables them to orbit the operation zone so that, with very few similar resources, it is possible to provide continuous coverage of the operations area. Of course, this continuous coverage can be accomplished with fighter aircraft, but requires a tremendous amount of resources and money.



Armed MQ-9 Reaper.
Photo: General Atomics

The second part demonstrated the benefits of armed drones in the targeting process. During the target development and prioritization, mission planning and force execution as well as assessment steps, armed drones distinguish themselves as being above and beyond other capabilities. As previously mentioned, for a target to be developed, it must be detected, tracked and assessed. Other sensors may also identify a target, but drones are virtually the only method with the mobility necessary to follow a mobile target for a very long period. We also saw that, during assessment, armed drones can stay in place to exploit intelligence, re-attack targets or conduct a battle damage assessment. Aircraft may also perform these tasks, but this exposes them to additional dangers. This part addressed dynamic targeting in step 5 of the targeting process. Armed drones again demonstrated their effectiveness in quickly executing missions against TSTs. Time and space factors are crucial for successfully engaging an important moving target, and armed drones' autonomy and large combat radius make them excellent hunters.

Lastly, we concluded that integrating drones into a rigorous targeting process would enable us to modify the system in place and allow Canada to be more independent internationally.

The use of drones internationally would fill three specific roles: drones could collect intelligence of interest solely to Canada, they could protect ground troops and they would be an excellent deterrent to insurgents. Regionally, in North America, drones would enable Canada to distinguish itself in its contributions to NATO and NORAD. Moreover, with the opening of the Northwest Passage, it will be necessary to ensure a permanent deterrent presence. Armed drones meet both of these criteria.

Having developed a rigorous targeting policy, Canada could now aspire to take the initiative in many parts of the world and not wait to be forced when it is time to support its southern neighbour. The targeting process gives commanders freedom of action on the ground while ensuring the legality and morality of engagements. CAF are mature armed forces that are prepared to acquire this type of drone. In any event, armed drones cause concern in the Canadian population. A procurement program will have to involve a very effective strategic communications campaign so that negative perceptions do not hinder the modernization of CAF.

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### **ABBREVIATIONS**

**CAF** Canadian Armed Forces

CFJP Canadian Forces Joint Publication
DND Department of National Defence

**DoD** Department of Defense

**ISR** intelligence, surveillance and reconnaissance

**TST** time-sensitive target

### **NOTES**

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### POINTS OF INTEREST







personnel are very familiar with. Though it is a part of every cockpit, fundamentally, automation is the idea that a piece of technology can perform a task for a human with little or no intervention. Machine learning is the next evolution of automation technology, and offers the RCAF the means to automate several organizational functions, thereby optimizing the effect of its personnel resources. By identifying areas of the organization that already contain the requisite features of a machine-learning system, the benefits of machine learning can be realized in some cases with minimal effort.

## Increasing productivity by employing automation is a viable and logical way to extend RCAF capabilities.

Automation isn't a new concept, but it's one that is often met with scepticism, at least initially. In the automotive industry, automated production processes are often associated with a concern that the labour force will be reduced. In the long term, however, we now know that this is generally not the case.1 Instead, there is a shift in the work force, with fewer unskilled positions, but more opportunities for highly skilled workers, resulting in a relatively constant size of the labour force, but with higher production rates.<sup>2</sup> For the RCAF, this is an appealing trend; much of its work force already consists of highly trained and skilled personnel who are, to some degree, burdened by tasks that could be autonomously completed by machine-learning systems. This would allow

more human resources to focus on higher-level issues, utilizing the very training and experience the RCAF has provided them, and improving overall productivity without increasing manning levels.

Increasing productivity by employing automation is a viable and logical way to extend RCAF capabilities. Even though Canada's most recent defence policy, *Strong, Secure, Engaged (SSE)*, calls for a significant increase to defence budgets,<sup>3</sup> the RCAF is already undermanned, and accelerating attrition rates may preclude its ability to increase manning levels measurably despite additional funding.<sup>4</sup> Implementing technology that can make human resources more available, therefore, enables the organization to expand its functionality by mitigating personnel constraints through workforce optimization.

The benefits of automation have already been realized by the RCAF. The increasing ability of technology aboard aircraft to execute tasks traditionally done by operators has led, in many cases, to reduced crew compositions. This allows the RCAF to operate the same number of aircraft with fewer aircrew, producing personnel who can be more advantageously employed.

The concept, therefore, is one the RCAF is familiar with, and although it has been around since the 1960s, machine learning has seen increasing popularity in recent years due to the availability of computing power and the expanding contents of digital databases,<sup>5</sup> which together enable new capabilities.

Think of machine learning as a tool that allows a computer system to autonomously respond to new situations without having been explicitly programmed to do so. Consider, for example, mortgage application information that is tracked and compiled into a database. If a machine-learning system is exposed to this database through learning algorithms, the system will be able to extrapolate lessons from the data set. Once this data, referred to as training data, is

Machine learning is a powerful tool that can be applied to many functions of the RCAF, and one example is image analysis.

understood by the system, it can then assess new information based on its extrapolations.<sup>6</sup> In this example, the system could predict whether an applicant is likely to default on their mortgage by comparing the parameters of new applications to the entire set of parameters surrounding mortgage defaults historically. Moreover, the system would be capable of processing these applications autonomously. This type of machine-learning system is referred to as a supervised system because the training data contains solutions; the result of historical mortgage applications would be known and included in the data set. Interestingly, however, machine learning can also be applied to data sets that do not contain solutions, which is referred to as unsupervised learning. Statistical data analysis is a good example of unsupervised machine learning that can be used to extrapolate hidden correlations within data sets.<sup>7</sup>

Machine learning is a powerful tool that can be applied to many functions of the RCAF, and one example is image analysis. A machine-learning system can analyse the contents of digital images and categorize them accordingly: pictures of monkeys, pictures containing three or more cars, or pictures containing weapon systems, for example. These types of systems are becoming increasingly capable with the expansion of open-source image databases that can be used to train these systems, and the reduced processing times that result from the powerful processors available. Applied to the field of intelligence, surveillance and reconnaissance (ISR), this would mean that relevant imagery can be separated from irrelevant imagery before it is presented to intelligence personnel for consideration, reducing the time required for analysis and, therefore, the personnel resources required to do so. Imagery from satellites or remotely piloted aircraft systems (RPAS) could be compared against a database of known surface-to-air missile (SAM) systems to autonomously assess and depict threat zones on a common operating picture, all without human intervention. For the commander, this means access to relevant information, even at 0300 when the staff are sleeping.

Image analysis as a capability would be relatively easy to assume due to the pre-existence of image databases and the prevalence of image-recognition research in the automotive sector. Machine-learning algorithms are currently being used with on-board cameras and sensors on cars to develop autonomously capable vehicles. These systems can identify road signs, compare those signs to a database of signs and deduce the appropriate meaning of the sign based on the coded meaning in the database of the sign it most closely resembles. For the RCAF, this means that a considerable framework of research already exists in the field of image analysis, and this framework can be refocused to achieve RCAF objectives with minimal effort.

The private sector is conducting a great deal of research into the modern applications of machine learning. Another relevant area for the RCAF is cyber security. Research surrounding the optimization and application of machine learning as a tool for intrusion detection in the cyber environment is abundant, and the best methods to employ machine learning in this context are currently being developed. RCAF owns and operates a large number of networks and assets that would directly benefit from the application of this research and, once established, the process could be largely automated to relieve personnel strains in the cyber and information-technology departments.

For the RCAF, machine learning could, in fact, be implemented into any system for which a large and representative database already exists. Digital image databases are an obvious example, but there are many others: annual posting plots, personnel career-management data, aircraft servicing records and asset scheduling histories could all be utilized as training data sets for machine-learning systems. Once the system has learned the relevant correlations within the data, it would be capable of optimizing posting plots, for example, based on identifiable priorities. This could take the form

of a posting plot that is optimized for cost, or restricts geographical moves for personnel who have moved more than six times, or who have children under age five—the possibilities are endless. A machine-learning system would be able to assess and solve these complex problems autonomously.

Of course, every system has vulnerabilities, and machine-learning systems rely heavily on the quality and size of the data sets they learn from. Large data sets are better than small ones, and the more representative and relevant the data contained therein, the more frequently the system will behave in the manner desired. 13 Still, adversarial opportunities do exist, and generally focus on exploiting anomalies in the system's training data.14 These anomalies are identified by iterative "perturbations" 15 and can be leveraged in a way that causes the system to incorrectly classify new information.<sup>16</sup> In the example of an autonomous car, this could lead to the misclassification of a stop sign as a yield sign; in a defence scenario, the misclassification of a SAM site as an industrial site. Machine-learning systems can, however, be designed to be resilient against adversarial manipulations by modelling the system in such a way that requires the adversary to make a large number of perturbations to discover the Machine learning is
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system's vulnerabilities.<sup>17</sup> The more perturbation required, the more likely they are to be discovered by surveillance protocols, and the more resilient the system becomes.<sup>18</sup> Unfortunately, resilience is inversely related to learning rates and accuracy, and a balance between a system's security and its performance should be task-tailored to the circumstances.

There are many areas within the RCAF where the application of machine-learning systems could realize benefits for the organization. Automation has already led to an improved capacity within the RCAF, and machine learning can contribute measurably to this goal. Machine learning is the next evolution of automation technology, and can offer the RCAF the means to automate organizational functions and increase productivity without increasing personnel manning levels. Although there are many conceivable applications of this technology, by identifying areas of the RCAF that already contain the requisite features of a machine-learning system, many benefits can be realized with minimal effort.

Captain (Capt) Cole McGregor joined the Canadian Armed Forces in 2012 under the direct entry program after completing a bachelor's degree from Queen's University. Following pilot training in Moose Jaw, SK, and Portage la Prairie, MB, he was posted to 429 Transport Squadron in Trenton, ON, where he currently serves as an aircraft commander on the CC177 Globemaster III. Capt McGregor was awarded the City of Portage La Prairie Flying Achievement Award and was named a distinguished graduate for both the CC177 Pilot Initial Qualification Course as well as the Air and Space Power Operations Course. He is currently

completing a Master of Business Administration through the Royal Military College in Kingston, Ontario. Capt McGregor has flown in support of Operation (Op) BOXTOP, Op REASSURANCE, Op UNIFIER, Op NABERIUS, Op PRESENCE, Op ARTEMIS, Op NUNALIVUT, Op FOUNDATION, Exercise (Ex) MAPLE FLAG, Ex MAPLE RESOLVE and Ex RIMPAC. He received the General Service Medal — Expedition for his service in support of Op IMPACT.

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# The Dynamism OF Space Exposes American Policy Gaps in Conflict Escalation

By Sergeant Smon D. H. Wells

here is a gap in international customs and laws that renders conflict-escalation standards in space unclear. Customs, laws, policies, regulations and treaties on space use exist at the international level, but there is not a single body of knowledge that governs the conduct of space affairs specifically in conflict. It is a collection of precedents and inferences that guides space operations. Modern militaries closely protect their and commercial actors' space systems in a precarious strategic situation that threatens rapid escalation into conflict. Space conflict-escalation doctrine should be developed to inform operations planning and risk assessment.

### OVERVIEW OF SPACE OPERATIONS

Space systems are a combination of independent or interdependent space assets, which the United States (US) Department of Defense (DoD) defines as equipment "which is or can be placed in space or directly supports space activity terrestrially." The object or group of objects do not have to be in space to affect the domain, and they do not have to be on Earth to affect terrestrial military operations either. The two most important functions in space operations are space situational awareness (SSA), which is an understanding of the objects in, the environment of, and the likely near-future developments in space; and space traffic management (STM), as in "the planning, coordination, and on-orbit synchronization of activities to enhance the safety, stability, and sustainability of operations in the space environment."

There is a need to resolve the gap in the law of armed conflict as applied to the space domain, which is increasingly becoming militarized and threatening to national security and civilian activities. As the leading space and military power in the world, the US should be used as a model to determine conflict-escalation norms in response to attacks on its space systems. At this time, operational-level triggers are less important than strategic factors like threats to critical infrastructure, military communications or the global positioning system (GPS).

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Although the US enjoys notable space superiority, its opponents' (China, Russia, Iran, North Korea and non-state actors) capabilities are quietly but quickly expanding. Increasingly capable threat actors require more agility to respond to. Identifying the thresholds of attacks deserving of armed response is difficult using international legal standards because asymmetrical tactics, which are increasingly employed and effective, cause indirect impacts and often have nebulous origins. Along with agility, the US needs deeper understanding of the potential consequences of threats.

Recent scholarship examines the gap between international laws and treaties and the current state of space activities, which is advanced much more quickly by technology than by consensus.<sup>8</sup> In addition to technology rushing policy development, discussion of the law of armed conflict, right of response, sovereignty over territory, non-intervention, coercion and explicit armed attack is often founded on terrestrial international legal standards<sup>9</sup> because no precedents exist in space. There is little basis or expertise from which to extrapolate a lead mark. Whether just-war principles will

apply uniformly in space as they do on Earth is unknown, but the international legal environment for the protection of space assets must match an operating space congested with approximately 22,000 known objects and potentially hundreds of thousands more.<sup>10</sup>

The White House's "Space Policy Directive-3, National Space Traffic Management Policy" is a positive development that begins to address shortcomings in this field. It directs activities in furtherance of SSA and STM science and technology; to enhance orbital-debris management; to facilitate US commercial leadership in the above; to improve information collection and sharing in order to maintain SSA; to develop best practices, policies and regulations for orbital operations; and to prevent or mitigate risk to satellites and communications systems.<sup>11</sup> It is a significant expansion of roles and responsibilities for responsible US federal organizations, including the National Space Council; the National Aeronautics and Space Administration; the Departments of Commerce, Defense, State, and Transportation; the Federal Communications Commission and the combined intelligence agencies.<sup>12</sup> For stakeholders, "Space Policy Directive-3" is a welcome reversal of the previous administration's cancellation of the space shuttle program, but it still does not clarify the US's precise position on protection of its space systems and preservation of key activities and capacities.

### AN INCREASINGLY COMPLEX ENVIRONMENT

Producing a basic map of conflict factors, triggers, actions and responses in the space domain could improve the clarity of escalation of armed conflict and determine likely friendly and enemy military courses of action. The question posed is, basically, "which strategic threats or actions increase the likelihood of armed responses to attacks on space systems?"

The ideal result of this inquiry is to clarify space power's military and grand strategic priorities in space as well as which hazards to space systems face the greatest risk. It could also identify military policies and international laws and customs that enable counter-attack in response to offensive actions on space systems. Clarifying pressures to space systems produces a basic estimate of risk of armed conflict instigated by kinetic or non-kinetic attacks on those systems.

This topic's relevance is heightened by the White House's issuance of "Space Policy Directive-2," which ordered review, simplification and protraction of commercial space as well as remote-sensing licensing criteria, 13 and "Space Policy Directive-3," which ordered significant capacity and activity

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increases in STM and SSA.<sup>14</sup> These orders were intended to rapidly escalate American commercial and military activity in space, which increases the possibility of contestation. As American military space activity seeks to maintain and expand American space superiority and access,<sup>15</sup> conflict situations with other space actors should be anticipated. The criticality of protecting space systems is underscored by a developing, new space race in which a multitude of actors with differing objectives occupy the same orbital area of operations.

The duality of space systems as both military and civilian technologies intertwines the vulnerabilities, priorities, and responsibilities of both sectors. This is best illustrated by the GPS, which was developed as a military guidance technology before popular implementation. American GPS policy is to provide uninterrupted availability, capacity meeting or exceeding demand, continuous global access for peaceful purposes as well as participation in international-cooperation and international-risk-mitigation activities. PGPS is still just one example of a range of critical functions supported by space systems: a RAND Corporation analysis of American and Japanese combined-force cooperation identified meteorology; communications, including command and control systems; military navigation and timing systems as well as SSA as key functions of intelligence, surveillance and reconnaissance supported by space systems. There appears to be little about space that is exclusively military or civilian.

Although the United Nations General Assembly adopted "Resolution 2222" in 1966 to prohibit deployment of weapons to space, <sup>19</sup> the advent of asymmetrical warfare has changed the nature in which conflict is operationalized, necessitating further clarification of the laws of armed conflict in space. The Center for Strategic and International Studies' "Space Threat Assessment 2018" includes expected threat actors China, Russia, Iran and North Korea, but it names Israel, Japan, India, Pakistan, Libya, Egypt, Ukraine and non-state actors as varying types and severities of threats to space capabilities, or as threats by employing them.<sup>20</sup> The report expands the scope of vulnerabilities to include asymmetric threats such as laser attacks on sensors and satellites, high-powered microwave weapons, radiofrequency attacks on communications systems, cyber threats and electromagnetic pulses, in addition to nuclear and missile threats.<sup>21</sup> The People's Liberation Army of China's (PLA) new Strategic Support Force poses an emergent threat: it is adept in the use of command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) and is aggressive and proficient in counter-space operations and capability development.<sup>22</sup> Operationally, there are many similarities between the cyber and space realms.

### CONCLUSION

Ensuring continuity in space systems is critical to military and civilian stakeholders. In a rapidly expanding area of operations with an ever-growing number of actors and capabilities, air and space forces should thoroughly analyse the legal and doctrinal constraints that apply to them. Understanding conflict thresholds will ensure measured application of force and help prevent excessive contestation of space.

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