BRIEFING NOTES

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THE UTILITY OF MICRO SATELLITE CONSTELLATIONS

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SUMMARY

The purpose of this report is to examine Canadian dependence on and the vulnerability of satellites. The strategic ramifications of which is highlighted by the growing anti-satellite capabilities of international rivals. As well as to propose solutions to this vulnerability.

CONTEXT AND BACKGROUND

Satellites enable and facilitate significant sectors of Canada's economy. Among these sectors, telecommunications, banking, shipping, and transportation are among the most reliant industries. Militaries also rely on satellites in the form of GPS systems that guide both soldiers and advanced weapons. Much like the civilian economy, militaries also depend on satellites for communication.

The ability to target satellites is increasingly becoming part of the evolving ECM and hybrid warfare doctrines of several rival states. Given the economic and military value of satellites, reducing their vulnerability is of paramount importance. The anti-satellite capabilities of rival nations have become more refined over time, and currently they pose a significant threat to the satellite infrastructure of Canada and its allies. Thus, there is a need to identify the vulnerabilities of satellites, as well as to reduce their vulnerabilities against ground based ballistic missiles and space based kinetic kill vehicles.

THE ISSUE

Satellites are indeed vulnerable to attack as has been proven by both China and the United States. In 2007 a Chinese anti-satellite missile (modified DF-21) successfully destroyed a satellite. The United States has also conducted two high profile anti-satellite missions. One mission where an F-15 fired a missile that successfully destroyed a satellite, and another where a ship-based RIM-161 destroyed a malfunctioning spy satellite. The Russian A500 ABM system slated to be in production in 2021, which, much like THADD is able to target satellites. With Russia's history of selling its current most capable SAM system, the chances of more states gaining the ability to target satellites from ground-based platforms will expand significantly.

While many of these states will purchase such systems for defensive reasons, this does not change the eventuality that they will have offensive anti-satellite capabilities. Disrupting satellites is also not uncommon. The shipping industry is particularly vulnerable due to its reliance on GPS and has been affected in the past. Cyprus is a good example of GPS jamming, as in and around the island, GPS signals are often disrupted for days at a time. ECM weapons such as the Russian Krasukha-4s deployed in Syria are often blamed for this. Jamming technology like the

Krasukha-4 while primarily designed to disable AWACS can also be used to disable low Earth orbit satellites[1].

SOLUTIONS

Weapons capable of destroying satellites are costly but not more so than their intended targets. For example, the American Navy's RIM-161 missile has an estimated unit cost of $18 million USD. The interception mission itself cost an estimated $100 million USD. It is difficult to estimate the cost of the modified DF-21 given China's lack of financial transparency. However, given its similarity to the Pershing II, it likely has a comparable unit cost of 11.6 million USD. Military low earth satellites such as the US Lacrosse radar imaging reconnaissance satellite costs an estimated $500 million to $1 billion USD. Given this, any of the methods listed above are relatively cost effective.

With the emergence of relatively low-cost micro satellite constellations (MSC), it has now become possible to make anti-Satellite warfare prohibitively expensive. MSC are currently being deployed and tested by private companies to provide global broadband internet. Using the estimated costs of SpaceX's Starlink constellation, it becomes evident that these satellites are far more cost effective than the means used to destroy them[2]. Currently, it is estimated that the cost of producing and launching 60 Starlink satellites into space is $50 million USD. This breaks down to a unit cost of roughly $416,666 USD. Given this, the cost of destroying a single Starlink node is anywhere between 27 to 43 times more expensive than the satellite's unit cost[3]. Given that these satellites are deployed in groups, it is possible that they can be deployed at a rate that exceeds the ability of many state's abilities to destroy them[4].

UTILITY OF MSC

MSC have several other benefits and possible uses and are not limited to providing communications. MSC can have earth observation satellites included in the constellation or can be designed to include such capabilities. By utilizing multiple, overlapping images, a high resolution can be achieved whereas the conventional method of using single satellite would produce low resolution imagery. Such capabilities would be highly valuable to SAR efforts, ice tracking and maritime tracking overall. In a similar vein, overlapping low resolution radar satellites can be used to track objects and their velocity if those objects are previously illuminated, potentially creating the beginning of a global AWACS system. Starlink satellites are designed to use phased array transmitters which should facilitate the inclusion of low frequency radars. Starlink has ten times the frequency range, 25 times

[1] Low Earth orbit extends up to 2000km into space.
[2] SpaceX is used for this calculation as they are currently the closest to completing a private micro-satellite constellation.
[3] While it is true that the low cost of the satellites in question is partially due to a lack of radar and imaging capability, modifying the satellites to include new capabilities may still allow them to be cost effective provided the increase in cost remains bellow that of the weapons used to destroy them.
[4] This is not currently the case but SpaceX plans to eventually be capable of deploying 400 satellites with a single launch.

the bandwidth, and nearly an order of magnitude better detection range than GPS satellites as well as a much finer range resolution. These technical improvements make it a far better base system for the inclusion of radar as compared to older GPS satellite models.

Starlink, unlike other conventional satellites, offers overlapping coverage creating a layer of redundancy in the event that the network suffers an attack or individual satellites begin to fail. The comms network is robust and self-healing in that it will re-route communications around disabled satellites. If the network is under attack, data can be routed around the affect satellites. The system is resistant to jamming as it requires contact with at least one of many ground stations to function correctly. The ability to relay communications to any other satellite in the constellation further increases the critical mass necessary to disable the network. Given that any satellite can send or receive data to and from any other satellite, communication can theoretically be routed around not only disabled satellites, but could bypass jammed or disabled ground stations, making surface-based ECM less effective.

Starlink's resistance to jamming is also due to its ability to calculate multiple routes and retry the data transmission until it reaches its destination. Currently, starlink is undergoing plane and drone connection trials with the USAF. Thus far, it has successfully provided a data connection to a reconnaissance plane. Therefore, the ability to provide global communications to friendly manned and unmanned aircraft seems plausible. Finally, given the sheer mass of the proposed Starlink constellation, it creates a form of deterrence as inflicting enough damage to disable it could potentially create enough debris to lock humanity out of low earth orbit. While MSC are potentially versatile, given the novelty of this technology all capability projections are theoretical at this time.

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