Do Multisat Constellations Make it Easy for the Bad Guy?

Lead Author: Brandon (BT) Cesul, brandon.cesul@us.kbr.com
Co-author: Edgar Ryan, edgar.ryan@us.kbr.com

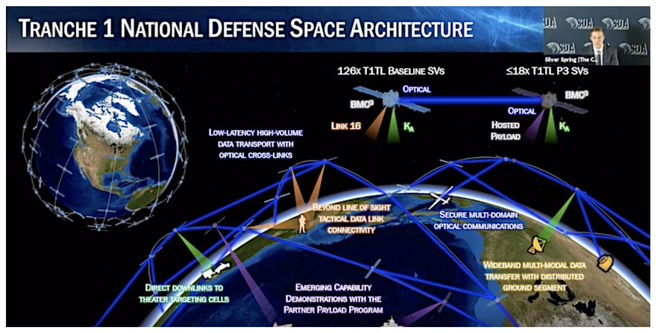
KBR National Security Solutions Group

With the United States moving toward fielding "massive multi-satellite constellation" architectures of small satellites for national security missions (to include dual-use commercial services), a radical change in the strategic calculus associated with space defense and space superiority is forthcoming. While many aspects of natural defenses of massive multi-satellite constellation architectures have been presented by U.S. government advocates such as the Space Development Agency, acquisition executives and strategic thinkers must consider additional factors for potential vulnerabilities and some potentially non-intuitive strategic impacts. Here, we specifically focus on the space situational awareness needs of potential attackers when considering counterspace actions against the MMSCs, and potential debris propagation resulting from a successful attack.

BACKGROUND

What are massive muti-satellite constellations (MMSCs)?

Singular mission-based constellations ranging from dozens to hundreds to thousands of individual smallsats (< 1000 kg mass) units operating in a similar orbital regime. This definition can be applied to more than military utility-based missions -Planet's Dove imaging satellite constellation, SpaceX Starlink and OneWeb communication satellite constellations, and Spire's commercial weather / radio frequency-based remote sensing satellite constellation are all examples of MMSCs built for commercial or non-defense-based customer bases.



Credit: SatNews, 16 March 2022

In the NatSec mission space, Space Development Agency is aggressively developing MMSC for a variety of missions to include missile sensing/launch warning, crosslink enabled communication, and alternate precision, navigation, and timing (PNT). Each mission layer is expected to be comprised of "shells" of orbit planes of similar altitude but differing inclinations and spacing of satellites.

Are MMSCs threatened?

Even commercial MMSCs are under threat of attack by a variety of actors as the utility of space-based information to inform or influence terrestrial military operations has been widely recognized, such as the use of Starlink satellites by Ukrainian forces in the 2022-23 Russia-Ukraine War.

Elon Musk says Russia is ramping up cyberattacks on SpaceX's Starlink systems in Ukraine

By Elizabeth Howell last updated October 14, 2022

SpaceX has been trying to help Ukraine stay online amid the ongoing invasion, which began Feb. 24.

SpaceX's Starlink internet service consists of a ground terminal (right) and antenna for high-speed satellite internet. (Image credit: SpaceX)

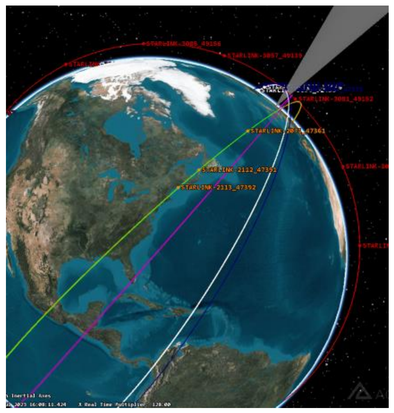
SpaceX's Starlink internet communications systems in Ukraine are experiencing increasing cyberattack from Russia, the company's founder Elon Musk said this week.

Credit: Space.com, 14 October 2022

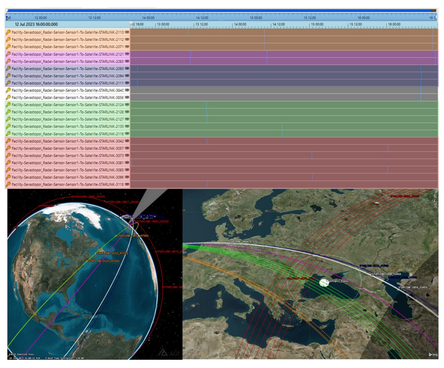
ANALYSIS

Here, we look at two questions: (1) does flying in an MMSC shell allow the attacker to gain targeting level information against multiple satellites by tracking only one satellite?; and (2) what is the impact of that attack on mission resiliency at a basic level?

Using Ansys STK basic, we analyzed the use of a single tracking sensor pointed in a zenith direction against multiple "chains" of Starlink satellites– satellites that are close enough in orbital elements to form a continuous string of satellites over a single terrestrial location in a short time span. We evaluated what minimum cone angle representing a field-of-regard for a tracking sensor was necessary where if the first satellite in a string was "tracked" the other subsequent satellites were also tracked without moving the sensor.



3D projection of multiple Starlink satellite "chains", with a static, zenith pointing field of regard projected from Sevastopol on the Crimean peninsula



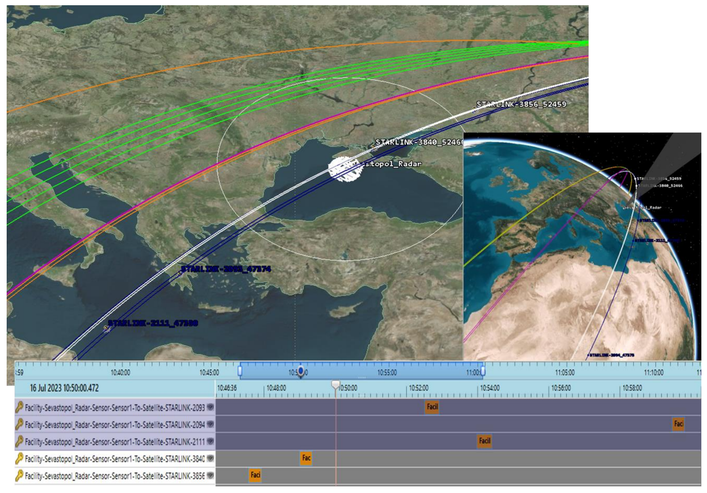
The size of the cone required to access multiple satellites in the same orbital plane is highly dependent on the spacing of the satellites in their orbit. Larger spacings along the orbit give fewer access opportunities for a static cone of a given size.

However, relatively small FOR angles would also be able to target an entire string in a single pass. Also, for wide area counterspace attack systems such as debris dispersal devices ("bag of gravel") or wide beam / phased array RF jammers, the larger spacings does not save a string since the variations in the orbital elements is still small.

One of the advantages of MMSCs is mission resiliency via proliferation. Counterspace weapon systems based on 1v1 engagement will stress the attackers space domain awareness capabilities by having to deal with many small, hard-to-find targets in slightly different orbits. But does the use of repeating "shell" constellations perhaps make the adversary's job of targeting, easier?

CONCLUSIONS

Our simplistic analysis shows that a relatively small field of regard cone (10 deg in most of our simulations) is able to track (or in the case of an RF jammer attack) deny access to multiple satellites in a constellation string in a single pass. In some of our simulations, as many as three separate "strings" were denied for a 15 minute period, calling into question the ability of the constellation to maintain mission compliance.



Additionally, the simple static cone is most effective at denying access to satellites that have trailing satellites in orbits that have a higher RAAN because Earth's rotation will put them directly in view. This configuration is common and considered desirable MMSC such as Starlink due to increased frequency of coverage. This basic CONOPS likely means that simpler "search fence" type of space domain awareness architectures may be more cost effective for weapon targeting by adversaries without complex 1v1 counterspace options. Strategy wise, this may mean that transitioning to a MMSC architecture may actually lower the threshold for adversaries to conduct counterspace operations. For MMSC architectures relying on the economics of small satellite design and functionality, this also probably propagates to increased need of orbit diversity and maneuverability in order to realize the defensive advantages of proliferated architectures.