FIBER OPTIC DRONES

POSING A SIGNIFICANT C-UAS CHALLENGE

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Fiber Optic Drones
Posing a Significant C-UAS Challenge

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Given the rapid pace of technological advancements on today's battlefield (particularly in AI) understanding the capabilities of adaptive technologies and unmanned systems is imperative, especially for Soldiers. These systems have demonstrated exceptional effectiveness on the battlefield, including lethal effects on troops. While the U.S. Army is not currently engaged in combat, it is exploring human-machine integration (HMI) and all Soldiers have an obligation to stay technically and tactically proficient in understanding the very real unmanned threats they will likely face. That includes understanding technological and operational nuances of drones.

One notable development Soldiers should pay attention to comes in the form of fiber optic spool-fed drones. On the front cover of the 26 March 2025 issue of the Stars and Stripes, LTG Joseph Ryan discusses how far the U.S. Army lags other militaries adjusting to fiber optic drones.[1] Meanwhile, any Soldier paying attention to technological advances in warfare in Ukraine over the past three years undoubtedly notices a cat and mouse game of drone versus counter-drone scenarios being played out on the battlefield. As one side develops a new drone capability giving it tactical advantage for a short period of time, inevitably the other side develops a counter technology to offset that advantage.


'We are so far behind'

Army lags in adjusting to use of un-jammable fiber-optic drones, general says.

Figure 1. 26 March 2025 issue of Stars and Stripes
LTG Joseph Ryan
https://www.stripes.com/branches/army/2025-03-26/army-fiber-optic-drones-17264379.html

One of the more recent instances where a developed innovation continues to evade counter technology and enjoy relatively unrestricted access on the battlefield, despite the adversary's best efforts to defeat it, is fiber optic spool-fed drones. These drones use a thin lightweight fiber optic cable that is unwound from a spool as it flies along to communicate with an operator. Utilization of a fiber optic cable makes it extremely difficult to detect and target such drones with some counter-unmanned aircraft systems (c-UAS). In this publication, we will dive into the concept of fiber optic spool-fed drones and how they work, consider their benefits, weigh their shortcomings, address potential applications for their employment, and reveal a few of the recent developments in successfully trying to counter them.

[1] https://www.stripes.com/branches/army/2025-03-26/army-fiber-optic-drones-17264379.html.

How Spool-fed Drones Work

Fiber optic spool-fed drones operate on a simple yet ingenious principle. A thin, high-strength fiber optic cable is wound onto a spool in a factory, encased in a protective shell of some kind, and then attached to a drone's body (usually to the bottom or rear portion of the drone). As the drone takes off, the cable unwinds from the spool. Because the fiber optic cable is extremely thin and lightweight, it can unwind at high speeds without generating excessive drag. Both video and command signals pass over the fiber optic cable, and as a result, allow a drone operator to see his target and surrounding environment clearly and in real time.

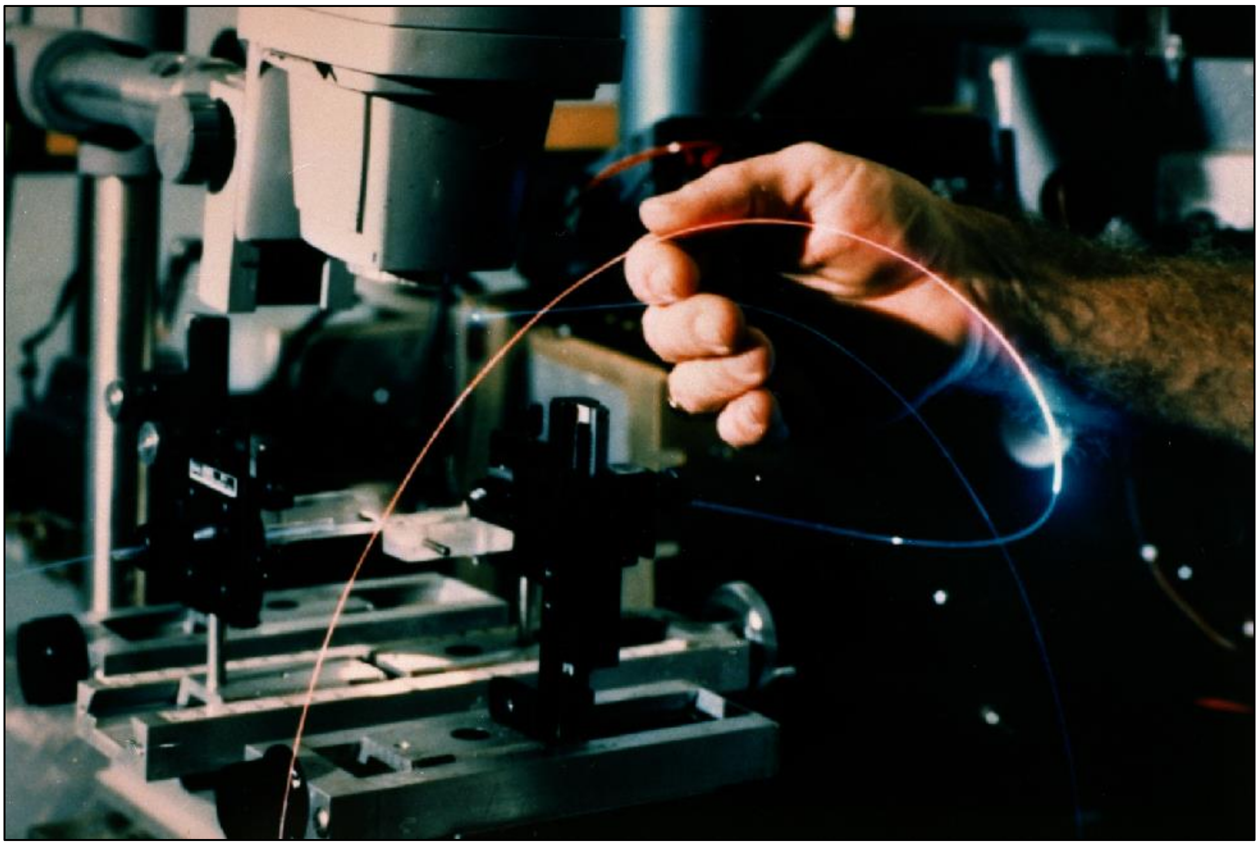

Figure 2. Fiber Optic Cable
Defense Visual Information Distribution Service (DVIDS)

Advantages of Spool-fed Drones

In a nutshell, a fiber optic drone operator can control the drone and see the battlefield and potential targets without worrying about electromagnetic interference. This is good news when considering the contested and congested operational environment in Ukraine from an electromagnetic emission perspective. While fiber optic drones contain electronic subsystems like flight controllers or electronic stability control systems that do emit electromagnetic emissions while operating, those signals are extremely weak and detecting them is difficult. Research will undoubtably continue developing ways to defeat and detect fiber optic drones, but current processes require physical access to the cables and have not proven very successful.[2] Social media posts regularly show Russians and Ukrainians successfully using fiber optic spool-fed unmanned aircraft systems and unmanned ground vehicles (UGVs) in Ukraine to continuously operate on the battlefield, despite robust electronic warfare systems on both sides. More specifically, the advantages of fiber optic drones include:[3]

High-speed, low-latency data connections: This allows real-time video transmission and command and control (C2) of the drone. Clearer images from the sUAS in real time enable better identification of inflatable vehicles and equipment used for deception purposes and allows ammunition to be conserved for targeting real vehicles and equipment. This is an important advantage as realistic decoys cover the battlefield more and more. Clearer images are also better for verifying successful strikes posted on social media platforms rather than a video ending in grainy signal interference.

Secure and reliable connections: Because the operator and his drone communicate on a fiber optic cable instead of radio waves, C2 disruption is negligible and risk of C2 interception is virtually nonexistent.[4] This is an important consideration when operating unmanned systems in electromagnetic (EM)-denied environments.

Resistance to counter-UAS systems: For several of the reasons already mentioned, fiber optic spool-fed drones (especially smaller first-person view drones) are difficult to detect in the electromagnetic spectrum (EMS). Therefore, they can avoid detection by many counter-UAS systems that rely on EMS detection for target acquisition and tracking. Thus, they have a better chance of surviving to mission completion.

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[2] https://youtu.be/ow9sxZOMtS8.

[3] https://youtu.be/ow9sxZOMtS8.

[4] https://en.defence-ua.com/analysis/two_pivotal_issues_regarding_fiber_optic_fpv_drones_on_modern_battlefield-13576.html.

Range and maneuverability: Despite expectations that the fiber optic cable's weight might limit its range or that the cable might get tangled with obstacles on the battlefield and break as the drone flies, surprisingly the opposite has proven true. Due to the hair-thin fiber optic cables wrapped tightly in relatively large spools, combined with the velocity and momentum of the drone, fiber optic cable drones flying at high speeds can release cables without getting tangled, even in forests.[5] The range for spooled drones continues to increase as drones become more powerful and batteries hold charges longer.

Access to denied environments: Fiber optic cable drones can operate in trenches, bunkers, and underground in tunnels where other drones using radio transmission cannot operate beyond line of sight. They can also operate without hinderance in mountainous terrain or behind and within thick-walled buildings in heavy urban terrain.

Less risk of interference: The number of drones operating on a battlefield varies for multiple reasons but there is a maximum number of drones that can effectively operate in a geographical area before they begin "stepping" on each other's transmissions, causing interference. Fiber optic drones do not interfere with each other electromagnetically, and so a larger number of fiber optic drones can operate within a confined space without interfering with each other's transmissions electromagnetically.[6] That is, of course, if they avoid flying too close to one another and getting caught up in each other's cables.[7]

[5] https://youtu.be/S_mmcLw4HD4.

[6] https://ts2.tech/en/jam-proof-unstoppable-how-fiber-optic-drones-are-rewiring-the-future-of-uavs/.

[7] https://defensefeeds.com/analysis/how-do-fiber-optic-drones-work/.

Disadvantages of Spool-fed Drones

Drone entanglement: While it is difficult to entangle a spool-fed fiber optic cable drone with its own line as it flies, it is possible for a drone to hit the line with its own propeller, which could result in a drone losing connectivity due to entanglement or cable bending/breakage. The longer the fiber optic line that trails a drone, the more difficult it is to control its flight because the drone tends to "sail" from the resistance of the cable.

Battlefield entanglement: Images of fiber optic cables strewn across the battlefield appear more frequently on social media as the battlefield becomes littered with them. While an individual fiber optic cable is thin, fiber optic tensile strength can vary but is typically around 300 pounds per square inch. Large numbers of tangled cables' combined tensile strength obviously complicate the entanglement situation and could present formidable obstacles to vehicles on the battlefield.

Figure 3. Fiber optic cables, like wires, reveal positions.
Defense Visual Information Distribution Service (DVIDS)

Pattern of life from fixed positions: As small as they are, fiber optic cables are noticeable from the right perspective, especially to the human eye when light glints off them. If multiple cables originate from the same firing position, it becomes obvious to observers and indicates a potential fixed-site position to target.

Circling objects: While they are somewhat resistant to entanglement, drones using fiber optics can more easily tangle themselves and/or break their cables when they circle objects. To date, the capability to reel in spent fiber optic cables, akin to a fishing reel, does not exist. Therefore, the more objects they encircle, the greater the chance of breakage and loss of video and C2 of the UAS.

Low-power video transmissions: Because of the way many fiber optic cables are connected to a drone operator's flight controller, a small bit of radio frequency transmission "leaks" in proximity to the operator, thereby potentially exposing their position on the battlefield. Again, this signal is very difficult to detect, but as research continues in detecting those small emissions, this could eventually pose an issue for avoiding detection.

Specialized flight training: Depending on how they are assembled, fiber optic drones can prove bulky and unwieldly to operate. Add the "sail" factor previously mentioned into the equation and you have fiber optic spool-fed drone operators that require specialized training to operate their drones effectively.

Increased carrying load: Load weight and bulk of fiber optic cable spools can limit the weight of munitions a drone can carry. So, larger and heavier spools can significantly reduce munition load.

Applications for Spool-fed Drones

Spool-fed drones have a wide range of applications to include:

Intelligence, surveillance, and reconnaissance (ISR)/messaging: Fiber optic spool-fed drones can be used for surveillance and monitoring applications. These drones passively receive signals to activate them and thus provide electromagnetically "undetectable" surveillance. Improved video through fiber optic cables allows better video recording for information operations messaging via social media.

One-way attack (OWA): One-way attack drones are some of the most widely used fiber optic spool-fed drones on the battlefield. Because they can avoid electromagnetic interference, OWA fiber optic drones have high success rates in hitting targets, even moving ones. Presumably, such drones could spearhead attacks, focusing on destroying enemy electronic warfare (EW) systems first, thereby enabling other drones to follow unimpeded.

Ambushes: A recent tactic demonstrated on social media involves a fiber optic drone flying to a predetermined position landing alongside a road or in a wood line behind concealment, stop its engines, and lay in wait until it sees a vehicle or another drone approach. Then it turns its engines back on, speeding to destroy its target relatively close in proximity.[8]

Delivery and resupply: The high efficiency and endurance of spool-fed drones make them an attractive option for package delivery applications, such as delivering medical supplies or ammunition packages to remote areas. Again, because they are relatively safe from detection, they can operate without revealing logistical source locations and because they can operate in electromagnetically denied environments, they can get medical supplies to wounded soldiers despite adversaries' attempts to prevent them.

Motherships: A fiber optic spool-fed mothership can launch several fiber optic spool-fed drones to strike multiple targets in EM-denied environments.

[8] https://youtu.be/eSE9NXRce-Y.

Mitigating the Threat

Beyond conventional methods to physically neutralize drones, such as running out and cutting the fiber optic cable of a drone that flies by, there are innovative approaches to counter the fiber optic spool-fed drone's effectiveness on the battlefield.[9]

Predict: Conducting intelligence preparation of the operational environment to determine the most likely locations to operate fiber optic drones from, then watching for indicators and warnings of drone operators moving to those locations, is an effective way to predict and target fiber optic drone operator sites.

Detect: Listen for drones. Fiber optic spool-fed drones are heavier than their smaller/lighter counterparts and are thereby louder when they travel as propellers compensate for the weight.[10] Keeping watch for movement and the glint from fiber optic cables can be difficult in the visible spectrum. However, online sources frequently report that fiber optic cables are clearly visible in the infrared (IR) spectrum.[11] Additionally, some online forums recommend using radar detectors to detect moving drones using spools.[12]

Avoid: Hide multiple wavelengths in the electromagnetic spectrum. Use visible camouflage and IR blocking material. If a fiber optic spool-fed drone is chasing you, try to get it entangled around objects or obstacles.

Protect: Dig in. Make sure you include top cover and no straight lines. Maximize cover and concealment. Drape nets over defensive positions' openings and over and throughout trenches, when possible.

Deceive: Use realistic decoys, as much as possible. Create fake weapons, alternate fighting positions, and fake vehicles. Because one would not leave a real vehicle out in the open but cover it with as much camouflage to blend into the surroundings as possible, do the same with decoys.

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[9] https://www.youtube.com/watch?v=9BT_-IN4Tzs.

[10] https://nexttools.net/how-loud-is-a-drone/.

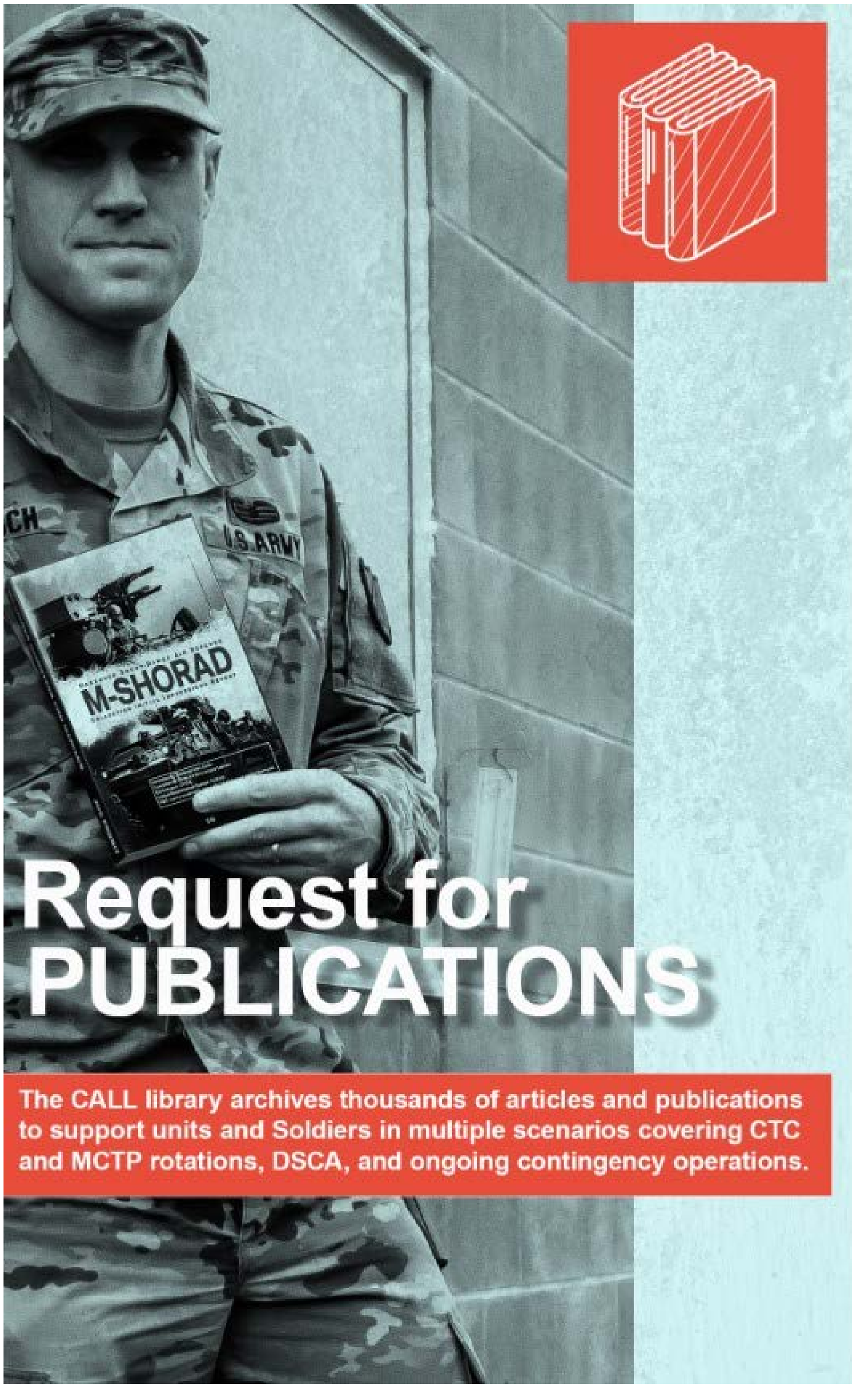
[11] https://www.spotterglobal.com/blog/spotter-blog-3/new-stealth-fiber-optic-guided-drones-fog-d-how-to-detect-them-12.

[12] https://www.spotterglobal.com/blog/spotter-blog-3/new-stealth-fiber-optic-guided-drones-fog-d-how-to-detect-them-12.

Conclusion

Fiber optic spool-fed drones represent a significant innovation on the battlefield when it comes to unmanned systems. Like any technology, they are not perfect, and eventually their Achilles heel(s) will be discovered. However, it is likely these types of drones will continue to serve unique purposes on the battlefield for the foreseeable future. It behooves one to learn as much as we can about them as the game of cat and mouse of unmanned technology versus counter-technology continues. It also behooves us to integrate fiber optic spooling systems into U.S. Army small unmanned aircraft system (sUAS) initiatives as the advantages are undeniable, especially in an EM-denied operational environment and given the C-sUAS capabilities to successfully interdict them are currently limited at best.

Figure 4. Fiber Optic Drone with Spool
U.S. Army Europe-Africa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