SATCOM for Net-Centric Warfare

MilsatMagazine

May 2020 issue

Artistic rendition of a satellite on-orbit over Earth is courtesy of NASA.

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NEW SOLUTION FOR MISSION CRITICAL APPS BY INMARSAT AND COBHAM

Inmarsat and Cobham SATCOM have launched a comprehensive new Broadband Global Area Network (BGAN) Push-To-Talk (PTT) solution to connect remote workers using vehicles across the globe.

The solution provides real-time data transfer and PTT communications to enable remote utilities, mining, aid and NGO, agricultural work and more, as well as for use in public safety and emergency response. Remote workers from a variety of industries brave hostile environments to deliver critical operations.

For engineers performing well-head maintenance, mining exploration teams on the hunt for new mineral deposits and aid and NGO organizations responding to humanitarian events, it is vital that all parties can see the position of their assets, share data and communicate in real-time. However, the very nature of the remote regions means that operations often occur where there is a lack of reliable cellular communications connectivity.

This means communications are not possible, leading to operational and safety challenges. Inmarsat's and Cobham's new solution responds to these challenges by using the company's BGAN solution, which offers industry-leading reliability of more than 99% uptime. Low form factor satellite terminals, such as the new Cobham EXPLORER 323, are mounted on vehicles providing real-time GPS, telemetry and PTT capabilities, through the EXPLORER Mobile Gateway anywhere in the world. This means control centers can efficiently and safely monitor the movement and performance of their vehicles, while enabling communications with crew wherever they are located.

An important feature of the solution is the integration with existing equipment on board. The Cobham EXPLORER Mobile Gateway integrates easily into any existing radio equipment, allowing the organization to keep and use their existing trusted equipment.

PRISM PTT+, a service powered by Cobham SATCOM's innovative PRISM (Private Routing & Intelligent System Management) technology enables the BGAN PTT Solution to switch between connectivity types such as UHF or VHF, 3G/4G and satellite making the solution cost-effective and easy to use. The switching process is unique in the market because it is completely seamless and offers an economical approach to voice communications.

Tara Maclachlan, VP of IoT, Enterprise, at Inmarsat, commented that the company's BGAN push-to-talk solution is set to offer a new level of resilient communications for organizations working in remote regions. It provides visibility of the movements and performance of remote assets along with real-time communications ensuring organizations benefit from enhanced efficiencies and safety levels.

Todd McDonell, President of Inmarsat Global Government, added that first responders and public safety teams need communications certainty, especially in operating conditions where fixed networks become disabled or degraded due to emergency events. The Broadband Global Area Network push to talk solution provides government users with a way to maintain Comms-On-The-Move (COTM) connectivity regardless of the situation on the ground. Providing voice, data and streaming services that can be easily integrated with the existing radio and data networks, the Broadband Global Area Network push to talk service provides extended coverage for traditional communications links.

Henrik Nørrelykke, VP, Global Sales & Marketing, Cobham, stated that the firm is excited to work with Inmarsat to launch the new BGAN PTT Solution. Using the Cobham EXPLORER Mobile Gateway, the PRISM PTT+ solution enables easy integration into any existing radio equipment, making it simple for organizations across a range of industries to upgrade their trusted 2-way radio capabilities.

www.inmarsat.com

www.cobham.com

DISPATCHES

VOX SPACE MISSIONS TO OCCUR FROM ANDERSEN AFB IN GUAM

VOX Space, the Virgin Orbit subsidiary, has signed a new agreement with the Department of the Air Force, allowing the company's LauncherOne system to conduct missions to space from Andersen Air Force Base in Guam.

VOX Space President *Mandy Vaughn* and U.S. Air Force 36th Wing Commander Brig. Gen. *Gentry Boswell*, signed the Commercial Space Operations Support Agreement (COSOSA) Annex in early April, setting the stage for the STP-27VP mission, VOX Space's first launch from Andersen Air Force Base.

Virgin Orbit and VOX Space first expressed interest in launching from the Pacific island of Guam in mid-2019. Due to Guam's low latitude and clear launch trajectories in almost all directions, the company's uniquely mobile LauncherOne system can effectively serve all orbital inclinations, such as delivering up to 450 kg to a 500 km equatorial orbit.

The U.S. Department of Defense (DoD) Space Test Program (STP) procured the STP-27VP launch with VOX Space under the Rapid Agile Launch Initiative (RALI), leveraging the Defense Innovation Unit's (DIU) Other Transaction Agreement. One of the first missions to fly on LauncherOne, the STP-27VP manifest consists of several cubesats from various government agencies performing experiments and technology demonstrations for the DoD.

After successfully demonstrating all major vehicle assemblies and completing an extensive flight test program, the Virgin Orbit team is in the midst of final preparations for an orbital launch demonstration expected soon.

Ms, Vaughn said the company is grateful to Brig. Gen. *Deanna Burt* and her team at HQ USSF/S3, as well as Wing Commander Brig. Gen. Boswell, Vice Commander Col. *Matthew Nicholson*, and all of the excellent airmen and women of the 36th Wing and Pacific Air Forces for their support. She added that Lt. Gen. *John Thompson* and his team at the Space and Missile Systems Center have also provided visionary leadership throughout this process.

virginorbit.com

RECONFIGURABLE TECH SPEEDS SENSOR DESIGN AND DELIVERY

The space market is booming. It's projected to grow to $1 trillion over the next two decades, according to a report from the Space Foundation.

In this fast-moving market, the aerospace and defense industry is looking for faster and more affordable ways to build satellites – and their payloads – and place them in orbit.

"*The one constant in this market will always be the actual space environment. And it's harsh; tons of radiation, extreme temperatures and other phenomena*," said ***Wallis Laughrey***, Vice President of Space Systems at Raytheon Intelligence & Space, one of four businesses that form Raytheon Technologies. "*Everything we build has to account for that, plus dissipating the heat that systems generate and fitting into a specifically-sized satellite.*"

Fitting into small spaces requires advances in all space tech, including electronics – individual, circuit-like boards that help a satellite realize its mission. They perform functions like detecting targets while on orbit, processing data or compressing images.

To meet the needs of the accelerating space market, Raytheon Intelligence & Space makes electronics that are not only small and light, but also open-architecture and reconfigurable.

"*Electronics can be built to go together, sort of like Legos*," said Laughrey. "*Because we can build and configure them faster and more affordably than custom-made electronics, it helps enable the rapid design and build of new sensors.*"

Today's electronics are up to 10 times smaller than before – one particular board is about the size, length and width of an electronic tablet. They can be stacked together and arranged in different ways. Unlike regular, earthbound electronics like we see on laptops, for example, these space-grade electronics are built to withstand extreme radiation and harsh weather.

"*Some electronic components will effectively short circuit when they're hit by radiation particles, while others degrade over time*," said ***Dan Petrovich***, technical director for RI&S Space Systems. "*We make sure all of our parts can withstand radiation and are designed to basically last up to 20 years.*"

Modern space electronics go beyond being configurable for different uses – some of the boards can even be re-configured while on orbit.

"*There are instances where we could update a system with a new capability by uploading a new file from the ground to the sensor on orbit*," said Petrovich.

As threats evolve, it's vital to quickly bolster existing space-based assets with new capabilities.

"*Plug-and-play electronics can give military, government and commercial customers more options to access space more affordably and rapidly,*" said Laughrey.

www.raytheonintelligenceandspace.com

A Raytheon Intelligence & Space engineer works on the Infrared Imaging Space Experiment, or IRISX. Electronics play a critical role in a sensor's ability to gather and process data.

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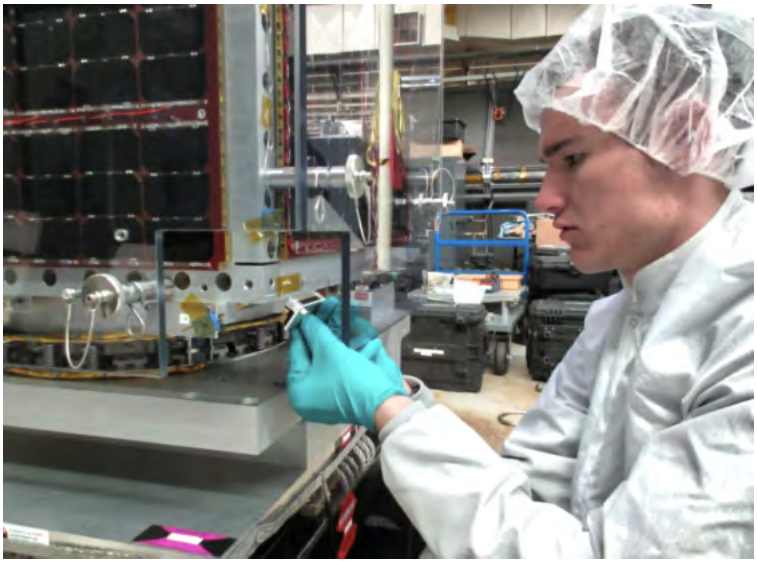
US AIR FORCE ACADEMY SMALLSAT TO LAUNCH



Work on the FalconSAT-8. Photo is courtesy of the U.S. Air Force Academy.

A satellite built by U.S. Air Force Academy cadets will launch into space on May 16 aboard the X-37B, Orbital Test Vehicle sponsored by the Department of the Air Force Rapid Capabilities Office and built by Boeing — this is the first time a satellite built and designed by cadets will catch a ride into space aboard the X-37B.

FalconSAT-8 will carry five experimental payloads, and members of the Cadet Space Operations Squadron will operate FalconSAT-8.

There's little doubt that the work by cadets will have an effect on the new Space Force, which opened for business in December and is designed to maintain and enhance the competitive edge of the Defense Department in space. Eighty-six cadets in this year's graduating class commission into the Space Force.

Good noted that few undergraduate programs allow their students to work on flight hardware and design and build their own flight components. Cadets are given hands-on work that allows them to get a feel for real engineering on real projects.

The U.S.A.F.'s X-37B Spaceplane. Image is courtesy of Boeing.

Cadets and instructors in the U.S. Air Force Academy's FalconSAT program pose for a group photograph at the Academy. They were directly involved in building a satellite scheduled to launch into space May 16 aboard the X-37B Orbital Test Vehicle, sponsored by the Department of the Air Force Rapid Capabilities Office and built by Boeing. This is the first time a satellite built and designed by cadets will catch a ride into space aboard the X-37B. Photo is courtesy of the U.S. Air Force Academy.

Lt. Col. ***Dan Showalter***, assistant astronautics professor at the Academy, said that as novel as this mode of transportation might be, the purpose for cadets in the school's space program is the same as it was when the school's space program began in the 80s. FalconSAT-8 is an educational platform for cadets.

He added that several cadets, including Cadets 1st Class ***Reagan Good*** and ***Claudio Yambao***, traveled to Cape Canaveral, Florida to deliver, test, and integrate FalconSAT-8 with the X-37B. This is like an engineering internship – experimental technologies for the Air Force are flown to evaluate their performance on-orbit,

The Academy's space program consists of aerospace experts, mechanics and engineers. The FalconSAT program serves as an academic platform for an array of aerospace industry and DOD experiments. Cadets design spacecraft and integrate payloads in the Space Systems Research Center with faculty support.

FalconSAT-8 is the Academy's capstone undergraduate systems engineering course managed by the school's Astronautics department.

Cadet Yambao said the space program's motto, "*Learning Space by Doing Space*," means cadets get to experience the postgraduate engineering world on campus and entails building and testing components of a spacecraft and understanding how it plays a role in the entire space engineering community.

SAFEGUARDING U.S. SPACE INFRASTRUCTURE

ManTech (Nasdaq: MANT) has launched Space Range, a cybersecurity solution that leverages deep research on offensive cyber to help protect U.S. military, intelligence community and commercial space assets from virulent cyberattacks.

A video viewable *at this direct link* shows the new solution in action via a live cyberattack on a replicated satellite command and control (C2) system created safely within the ManTech Space Range.

The replicated satellite hack showcases Space Range's ability to find hidden vulnerabilities, misconfigurations and software bugs on precise network replications, empowering customers with the knowledge to prevent and defeat real-world attacks.

As Space Range evolves beyond this first phase, ManTech will expand solution capabilities to protect space systems from the full spectrum of potential cyberattacks.

Rick Wagner, President of ManTech's Mission Cyber & Intelligence Solutions (MCIS) Group, said space is a war zone. In a world where hostile nation states work around-the-clock to compromise networks and infrastructure, Space Range fills the vital role of protecting space assets from the ground up – including complex ground stations and network transport facilities.

investor.mantech.com

MULTIPLE ORDERS FOR EMS' COBRA TERMINALS

Electro Optic Systems Holdings Limited has announced their wholly owned subsidiary, EM Solutions has recently closed contracts to deliver their Cobra Maritime Satellite Terminals to four allied Navy end users in the EMEA region. These contracts, valued at approximately $14M, will be delivered through 2020 and 2021.

In addition to EM Solution's strong existing order book with the Royal Australian Navy, these contracts result in a record backlog for the company, six months after being acquired by EOS.

With its Cobra terminals now in use or on order with six of the world's largest navies across four continents, the contracts further validate the acceptance of EM Solutions satellite communications products as a technology of choice to some of the world's pre-eminent naval end users.

Operating at X-Band, Military Ka-Band and Commercial Ka-Band and certified for operation on major global networks such as WGS and Inmarsat GX, the Cobra terminals provide users with robust and resilient beyond line-of-site communications with unprecedented flexibility and assuredness for their operations at sea.

EM Solutions CEO, Dr. ***Rowan Gilmore*** said, "*These export sales help confirm EM Solutions as a trusted supplier of broadband satellite communications to defence forces around the world. The orders come on the back of the tremendous support the company has received from the Australian Department of Defence in the development and commercialisation of its Cobra terminals.*

As we continue to support the Royal Australian Navy with deployment of Cobra terminals on multiple vessel types, the confidence shown in Australian space communications technology by multiple allied navies is a strong endorsement of the sovereign capability that has been fostered by Australian Defence Industry Policy".

The Group CEO of EOS, Dr. ***Ben Greene***, said, "*The global success of our Cobra technology underscores its suitability for a wider role in global satellite communications. Cobra is presently the most versatile satellite communication terminal available, providing users with access to both MEO (mid earth orbit) and GEO (geostationary orbit) satellites in multiple military and commercial bands, and from rapidly manoeuvring platforms such as fast naval vessels.*

Cobra is now being extended in scale and adapted in spectrum for more platforms, and a wide range of potential roles in the EOS deployment of next-generation communication satellites in MEO."

In parallel with the negotiation of these recent contracts, EM Solutions expanded its presence in Europe in cooperation with long-time partner UR Group based in Milan, Italy.

This expanded cooperation has provided EM Solutions with a direct business development presence in the region and provides a platform from which more comprehensive customer support and service capabilities can implemented as required.

Given the current challenges of the global pandemic, the company's direct presence in North America and now Europe has cushioned the impact of supporting new and existing customers in these markets at this time.

www.emsolutions.com.au

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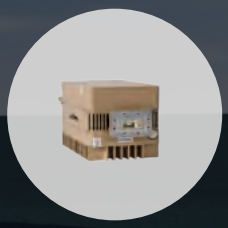
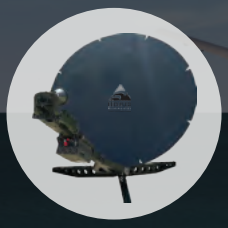


X-Band SSPAs/BUcs
GaN & GaAs configurations



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THIS STORM IS MIL-STD-810H CERTIFIED

CopaSAT, LLC, has announced that the company's STORM terminal is now MIL-STD-810H certified while also being qualified on the IntelsatOne Flex network.

Developed with CopaSAT's unconventional warfare customers in mind, the CopaSAT STORM SATCOM terminal was demonstrated to withstand a series of environmental stress tests including shock, vibration, extreme temperature, water infiltration and more.

The SATCOM-On-The-Move (SOTM) terminal has been tested on both tactical land vehicles, such as MRZRs and tactical maritime vessels, making it field-ready, or even combat-ready.

As of March 12, 2020, the CopaSAT STORM also became an IntelsatOne Flex qualified terminal, authorized to operate on Intelsat's GEO satellite fleet, including its HTS network.

The CopaSAT STORM terminal features a Kymeta™ u7 flat-panel, Electronically Steered Antenna (ESA), iDirect 950 modem and a 25 Watt Block Up Converter (BUC) for ultimate high- performance satellite communications on-the-move or on-the-pause.

This fully integrated terminal provides a mobile hotspot using SD-WAN to select between cellular, Wi-Fi or satellite networks for optimization, failover and balancing.

The STORM terminal also accepts external GPS sources such as Defense Advanced GPS Receiver (DAGR) for selective availability and anti-spoofing.

An optional bracket for an external MANET handheld radio is available with power and Ethernet at the bracket. The STORM offers many additional options for maximum flexibility and usability.

Obie Johnson, CEO, CopaSAT, said it is exciting to offer the first-ever MIL-STD-810H tested SOTM/COTP terminal using the Kymeta™ u7 flat-panel Electronically Scanned Antenna. This communications capability will be a force multiplier and is an affordable and high-throughput solution for multiple military applications. The company is now in general production for the CopaSAT STORM at the firm's new Largo, Florida, state-of-the-art facility.

www.copasat.com

NEW FOUNDING MEMBER FOR THE SPACE INFORMATION AND ANALYSIS CENTER

The Space Information Sharing and Analysis Center (ISAC) and the National Cybersecurity Center (NCC) have announced that the University of Colorado Colorado Springs (UCCS) has joined the Space ISAC as a founding member — Gretchen Bliss, the Director of UCCS Cybersecurity Programs, will sit on the Space ISAC Board.

UCCS and the NCC, which serves as the operational arm of the Space ISAC, have been partners since the NCC's founding. Now, as UCCS becomes a Space ISAC founding board member, that partnership extends to the Space ISAC and enhances the ISAC's access to Colorado's space and cybersecurity ecosystems and one of Colorado's higher education institutions developing cybersecurity engineers.

Bliss said that UCCS is uniquely positioned to provide the cybersecurity workforce and research that industry and government are looking for with the headquarters of the Space ISAC, National Cybersecurity Center and Exponential Impact located in the organization's Cybersecurity Building. Students and faculty will be able to collaborate with the leading organizations, government, academia and industry in the space and cybersecurity fields on education, training and research to provide timely, effective solutions to hard problems at the national level.

Frank Backes, Chairman of the Space ISAC Board and Senior Vice President of Kratos Federal Space, added that UCCS has been a thought leader in the Colorado Springs space and cybersecurity communities.

The Space ISAC is the only space-dedicated ISAC and is made possible through the investment by its board and founding members. Its board, which held its third meeting in March, is comprised of leaders in the space industry, cybersecurity sectors, academia, and FFRDCs, and includes Kratos Defense & Security Solutions, Inc. (NASDAQ: KTOS), Booz Allen Hamilton (NYSE: BAH), MITRE, SES, Lockheed Martin (NYSE: LMT), Northrop Grumman (NYSE: NOC), Parsons Corporation (NYSE: PSN), Purdue University, the Space Dynamics Laboratory, the Johns Hopkins University Applied Physics Laboratory, the Aerospace Corporation, and the University of Colorado Colorado Springs.

s-isac.org

THINKOM GOES THIN + LOW

A series of interoperability tests were conducted that brought out very positive aspects for ThinKom Solutions, Inc., demonstrating the compatibility of its core antenna technology with a low-Earth orbit (LEO) satellite network.

The tests took place during the first quarter of 2020, using commercially available airborne-certified hardware, including a ThinKom Ku3030 phased-array antenna subsystem and a Gogo radome, adaptor plate and power amplifier that together comprise the "2Ku" aero satcom terminal.

The 2Ku terminal demonstrated rapid acquisition and tracking of LEO satellites and provided continuous connectivity over all operationally relevant elevation angles.

The switch time between individual satellite beams was less than 100 milliseconds (ms), and handoffs between satellites were completed in less than one second.

Switches between LEO and geostationary (GEO) satellites were also achieved with similar results.

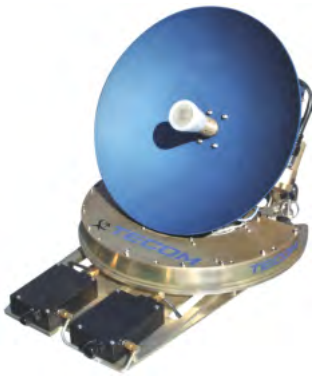
The measured terminal performance demonstrated the potential that the combination of ThinKom antennas and LEO solutions will provide, with throughput rates in excess of 350 Mbps on the downlink and 125 Mbps on the uplink, at latencies of less than 50 ms.

Bill Milroy, CTO of ThinKom Solutions, said that LEO satellite networks have the potential to be transformative to the in-flight connectivity experience, but also place new stringent demands on the antenna systems used to track and connect with the rapidly moving satellites. This important demonstration is another milestone verifying that our antenna technology operates effectively in the LEO environment, which is a key requirement for airlines in terms of enhanced network resiliency and flexibility.

ThinKom has successfully tested its Ku- and Ka-band COTS phased-array aero antennas across commercial and military frequency bands and a wide range of GEO and non-geostationary (NGSO) satellites over the past 12 months. In all cases, the phased-array antennas have consistently demonstrated high throughput operation and rapid reliable handoffs, including both intra- and inter-satellite switching.

thinkom.com

SMITHS INTERCONNECTS ANTENNA CONNECTS WITH GLOBAL XPRESS APPROVAL



Inmarsat has given approval to Smiths Interconnect KaStream® 5000 MK II antenna system for use over the Inmarsat Global Xpress network.

The lightweight KaStream® 5000 MK II antenna system is a fully integrated solution that is optimized for use over the Inmarsat Global Xpress Ka-band network and supports commercial and military modems. It can be used in tail-mount, hatch-mount and roll-on roll-off installations combining the Radio Frequency (RF) electronics, antenna aperture and positioning system in a single Line Replaceable Unit (LRU). This wideband, high-throughput terminal features a 12-inch diameter aperture and weighs less than 25 lbs (~11.4 kg).

Using a Global Xpress subscription, SATCOM as a Service, the terminal provides always-available access to high-throughput, reliable, secure connectivity, anytime and anywhere. Operation on Inmarsat's military Ka-band steerable beam ensures interoperability with military satellite systems, delivering redundancy, protection, scalability and global portability.

In U.S. government operation since July 2014, Global Xpress has established itself for reliable communications across land, air and sea for assured mobile connectivity and compatibility with government satellite systems.

Steve Gizinski, Chief Technology Officer, Inmarsat Government said that their government customers demand commercial and military Ka-band access on aeronautical platforms. This announcement demonstrates their commitment to meeting this need by responding with Global Xpress commercial and mil-Ka terminals for users operating across multiple environments. They are pleased to work with Smiths Interconnect to expand their offerings with the lightweight KaStream® 5000 antenna system, which is compatible with MILSATCOM and enables Beyond Line of Sight (BLOS) connectivity for a range of Airborne Intelligence, Surveillance, and Reconnaissance missions.

Ralph DeMarco, Vice President of Business Development and Sales at Smiths Interconnect added that theirKaStream® 5000 MK II broadband antenna system is truly unique in the market by offering access to global wideband commercial and military networks. They are very pleased to be partnering with Inmarsat to offer fast, reliable and efficient connectivity on and off the aircraft worldwide.

www.smithsinterconnect.com

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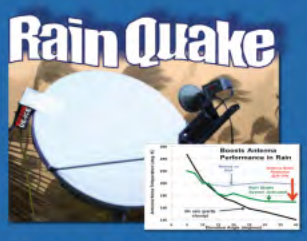

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NEW ORDERS FOR LITE COMS VSATS

Lite Coms LLC recently received new orders for VSAT terminals and the company's Tactical Modem Assembly (TMA) for delivery to users in Columbus, Georgia.

The Carbon Fiber antenna was selected for performance and small, total volume. The antenna will be used with the Lite Coms TMA. This advanced Tactical Modem has an integrated iDirect 950 satellite modem and is the smallest, lightest, tactical packaging of this modem on the market. The Lite Sat TMA-950-T has a feature rich LCD display, multiple data ports as well as Ethernet and serial control ports.

Lite Coms works to achieve the best physical layout and a Human Machine Interface (HMI) on the market. The company's goal is to ensure that their products provide both Comms Operators and General Purpose Users a simple, yet feature rich, experience. The Lite Sat TMA-950-T is also integrated into the Lite Coms 1.3 and 2.2 meter auto squire terminals.

Bob Jacobson, the President and CEO of the company, said the growing confidence the user community is showing in the offerings of Lite Coms is exciting. The company has customers around the globe coming to us to deliver higher throughput, innovative packaging and a more efficient user experience. Lite Comms manages to do this work in a fraction of the time of the competition.

Additionally, the company has engaged in a partnership with AvL Technologies, Mission Microwave, Orbital Research and iDirect Government as the firm continues to modernize their VSAT offerings.

The AN/TSC-248 family of terminals are comprised of an integrated Lite Sat 1.3 meter Auto Acquire terminal with the Lite Sat Tactical Modem Assembly (TMA) that features the iDirect 950 satellite modem. LNB's from Orbital and the Lite Coms Wide Band Custom Ku- LNB and SSPAs from Mission Microwave are integrated in this product into a light weight, rapid set up, small pack-out system with an optional, user-friendly GUI.

Mr. Jacobson stated that this highly transportable terminal packs smaller than many sub-one meters, assembles in minutes and delivers incredible performance and throughput at a highly competitive price. The product is the result of countless hours spent with customers whose input strongly influenced the final design and configuration.

www.litecoms.com/our-products/

USAF'S SUPPORT TO SPACE INDUSTRIAL BASE

In response to COVID-19, the Department of the Air Force is posturing to identify and provide support to the space industrial base, assessing sectors most impacted by the pandemic while creating an environment where companies in need can compete fairly in the event of supplemental federal relief funds.

Dr. *Will Roper*, Assistant Secretary of the Air Force for Acquisition, Technology and Logistics and U.S. Space Force Service Acquisition Executive, said the space industrial base is critical to the nation's military and economy. The Space Force Acquisition Council held an emergency session to synchronize response to fragile supply chains, at-risk workforces, and receding commercial markets and will continue to work with the Department of Defense and Congress to get additional help.

Roper said the council directed a comprehensive survey go out to space industrial base sectors, including members and non-members of the Space Enterprise Consortium, several federally funded research and development centers (FFRDCs), and pertinent think tanks. The survey focuses on three distinct priorities:

1. *Emerging supply chain, cleared workforce, and markets under immediate distress*
2. *Real bills caused by COVID-19 with the goal of minimizing existing program schedule risks*
3. *Stimulus: Small space vehicles, micro-electronics and other key areas for long-term sustainment*

Dr. *Christopher Scolese*, NRO director, added that assured access to space coupled with a strong space industrial base are fundamental to national security. The National Reconnaissance Office is committed to working with the Space Acquisition Council and with the U.S. Space Force to ensure the stability of the space sector.

While Air Force officials recognize major suppliers and "prime" companies have been affected by COVID-19, an immediate concern is with tier three and tier four suppliers and vendors, as well as small companies, especially in the small launch, commercial satellite communications, and micro-electronic sectors.

Gen. *Jay Raymond*, U.S. Space Force Chief of Space Operation, noted that the COVID crisis must not undermine critical space industries. Given the threat to space capabilities posed by potential adversaries, the U.S. space industrial base must remain strong — the best in the world at developing national security space systems.

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REDUX: PUBLIC/PRIVATE PARTNERSHIPS

THE WEST'S MILITARY TECHNOLOGY IMPERATIVE

By John Beckner, Chief Executive Officer, Horizon Technologies

In 2019, Orbital, via an Antares 230, facilitated the launch of the first of the UK IOD (In-Orbit Demonstrator) programs , run by the UK Satellite Applications Catapult.

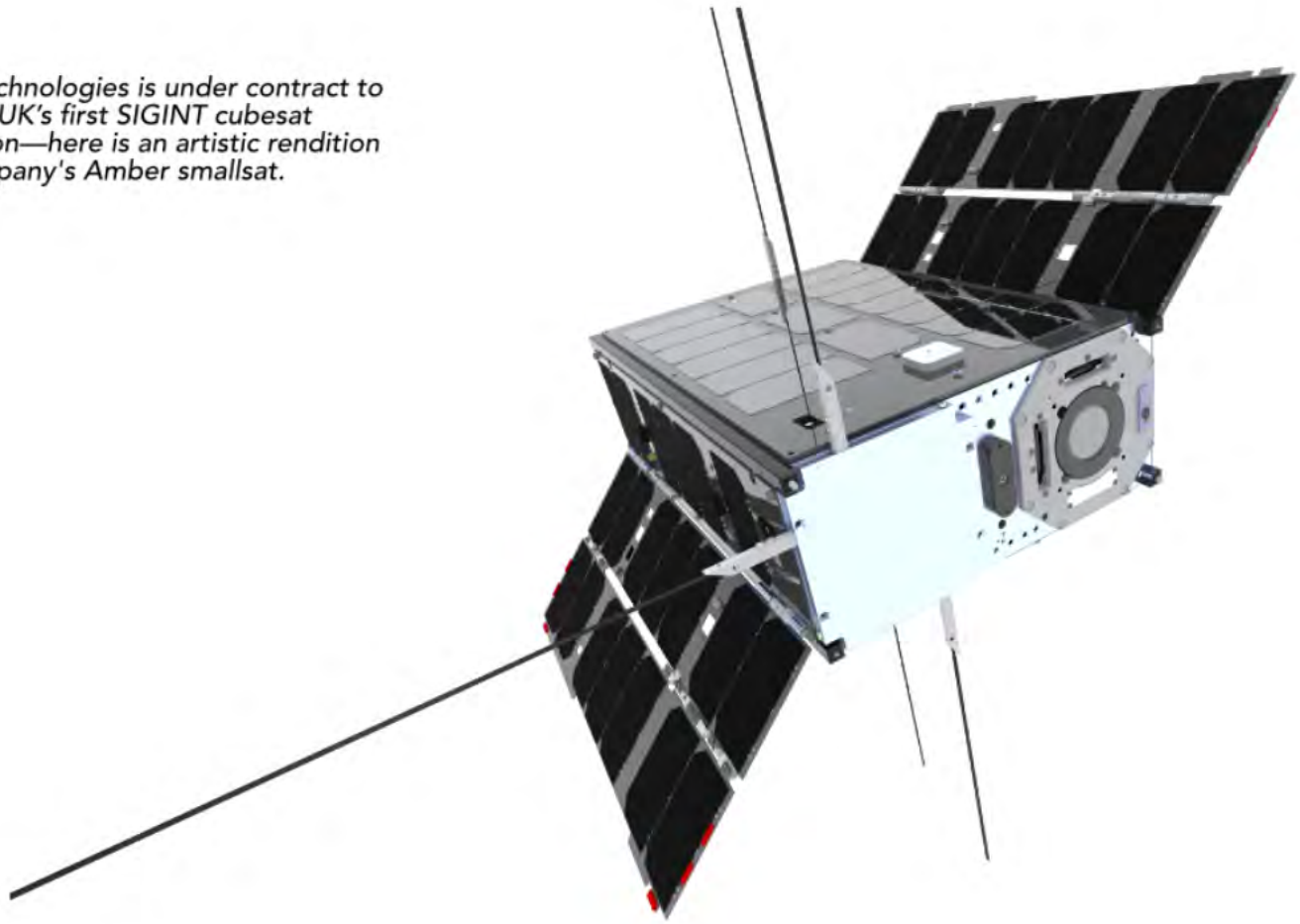
The satellite carried Colorado-based, Orbital Micro Systems' (OMS) payload to detect micro-weather via a space-based microwave radiometer sounding spectrometer, retrieving temperature data in eight, vertical, atmospheric layers. OMS is also teamed with Lockheed Martin UK, and provides the blueprint on how successful Public/Private partnerships work as they enter the lucrative GeoInt market.

This mission is proof that the UK's approach on incentivizing US/UK industry to work with government in getting cutting-edge technology deployed and in operation quickly is working. The UK model of Public/Private partnerships in aerospace differs from the that of the US but offers lessons to the US and other Western powers.

The IOD-1 GEMS launch proved that the government supported innovation schemes can play a key role in the West's attempt to compete with China; economically and militarily. As pointed out in a recent paper by Stanford's Cyber Policy Center, Dr. *Anthony Vici,* the former CTO at the NGA (National Geospatial Intelligence Agency,) noted, "*Simply increasing national security funding or R&D spending will not ensure victory against a competitor able to outspend the United States. Instead, we will need once again to revolutionize public-private partnerships to meet the challenge, harnessing more efficient ways of developing and implementing new technology*."

Anthony's paper lays out a number of excellent suggestions on how public/private partnerships can be harnessed in the US to get private companies to move technology from TRL (Technology Readiness Leve) -1 (Basic Research) up to TRL-8 (System Test, Launch, and Operation) much quicker than before, and be allowed to keep (or jointly own) their IP which is critical for many startups looking to success in the commercial as well as the aerospace/military market.

The problem for Western governments is quite clear. Either they can remain with their slow cycles of tendering, procuring, and



Horizon Technologies is under contract to launch the UK's first SIGINT cubesat constellation—here is an artistic rendition of the company's Amber smallsat.

implementing new technology, or they can incentive industry to spend their own money, keep their own IP, and let industry profit on technologies which have dual commercial/government value. Under the Department of Defense (DoD) traditional procurement process, over "*requirement-ization*" (as some call it) reigns supreme, and stifles innovation.

UK startup Horizon Technologies is at "*ground zero*" of the public/private effort in the UK as they were selected for 3rd Innovate UK-funded IOD mission by the Satellite Applications Catapult. The IOD-3 Amber™ mission will see the first of a constellation of six (6) cubesats launch into Low Earth Orbit (LEO) to offer the UK and Allied nations a Maritime Domain Awareness (MDA) data product via "*Commercial SIGINT*" sensors on the Horizon Technologies payload.

These sensors will track ships' AIS signals, maritime radars, SatPhone usage and even illegal GNSS spoofers, which are increasing in prevalence. This is an innovation partnership whereby the UK government essentially funds 80 percent of the first satellite into orbit and operation; Horizon is required to invest the firm's own money and provide the cubesat payload to the Catapult for £1.

Horizon didn't bid to any government requirement, or specification, tender or study program. They simply saw a worldwide military/civilian need to combat so-called maritime "*dark targets*"; those vessels who turn off their AIS transponders while engaging in illegal activity.

Think of piracy, illegal fishing, smuggling, transshipments, and Iranian oil shipments. Under the UK's world-leading policy of incentivizing and funding cutting-edge technologies, small companies can move from "*PowerPoint to a cubesat in orbit*" in less than 24 months — that is, essentially, TRL-4 to TRL-9 in that short period of time. As someone who's been involved in aerospace, in and out of government, since 1982, this is nothing less than incredible.

Under the IOD program, the Catapult essentially acts as the program manager between the payload provider and the bus provider (in the case of IOD-3, AAC Clyde Space in Glasgow). The Catapult are delivering Innovate UK's vision to harnesses UK space/satellite expertise, and ensure that the IOD missions come to fruition, meet their goals, and provide economic growth for the UK.

There is a three (3) month down-select process whereby the leading candidates/technology have to present to a cross agency UK government board. Presented with a space-based GeoIntelligence (GeoInt) data source which they didn't have to fund or support, it's no wonder that the UK MoD has greeted the Amber™ program with open arms as have an increasing number of both large and small Allied countries which urgently need MDA/GeoInt data in their countries/regions with latency of less than one hour.

The current situation in the United States is different, and is focused not so much on public/private partnerships, per se, but rather in finding ways to get non-traditional technology companies (like those in Silicon Valley) into the DoD acquisition system and fielded. With an R&D budget of $55.4 billion (CY 17), the DoD is in a vastly different position than a much smaller European country like the UK.

As stated above, it's very clear that there is a "*technology race*" on with China. That country doesn't need innovation from private firms (which it lacks, in any case). It fuses commercial/military intelligence gathering to its topflight (often Western-educated) military R&D centers and spends whatever is required to move ahead with new military technology; read AI, cryptography, hypersonic air vehicles, etc.

In the US, the first step to using non-traditional, private industry to assist the DoD came with the formation (under the Obama Administration) of the DIU agency in 2015. While not a true, Public/Private partner such as the UK IOD program, it has proven to be a strong "*first step*" in getting non-traditional commercial companies to provide accelerated dual technology to the DoD.

According to ***Mike Madsen***, the DIU's director of strategic engagement (in a recent issue of *National Defense*)," *we start with the DoD customer with a DoD problem, and put it out to the tech sector […] to help solve our problems. Recently the DoD gave DIU new contracting authorities in order to cut through the bureaucracy. In total, DUI has awarded about 150 contracts to 122 non-traditional vendors with 66 being first-time suppliers to the military.*"

The beauty of the DIU approach is that, due to its locations in Mountain View, California, and Austin, Texas, it can easily reach out to the commercial sector and VC investors to find the correct commercial technology needed by the DoD. Currently, the top five DIU focus areas are AI/Machine Learning, Autonomy, Humans Systems, Space, and Cybersecurity.

However, according to a recent *Federal New Network* article, "*Since 2015, millions of dollars have been invested in the DIU, and the agency watched as some of its projects fell flat. Only about 23 percent of the organization's completed projects ended up in the hands of troops.*"

Innovative counter-cyber and counter-drone technologies were a major part of the 23 percent, and these programs, despite some turmoil, have produced results. On the downside, Congress isn't particularly thrilled with the 77 percent of programs which didn't make it to contract.

The individual services in the US are not being left behind, either. The US Air Force Research Lab (AFRL) and AFWERX have partnered to form the U.S. Air Force Small Business Innovation Research (SBIR) program whereby small companies can obtain initial USAF funding outside of the traditional DoD system.

Established in 2017 by the Secretary of the Air Force, "*AFWERX is a catalyst for agile Air Force engagement across industry, academia, and non-traditional contributors to create transformative opportunities. The core mission of AFWERX is to improve Air Force capabilities by connecting innovators, simplifying technology transfer, and accelerating results.*"

AFWERX works together with the AFRL which streamlines the SBIR process. The AFWERX/SBIR process defines requirements and technologies of interest to the USAF and gives small businesses the chance to get into the market and start generating revenue. The AFWERX program has awarded $220 million since 2018 in contracts to small business.

The EU has not yet embraced the public/private partnership technology route. The EU does have its own program to (1) start competing with China and Russia as well as (2) become more technology independent of the US and at the same time supporting competitiveness and innovation in the military/aerospace sector.

On June 7, 2017, the European Commission officially launched the European Defence Fund. This Fund has the goal of financing military R&D from an overall EU perspective.

The main priorities are autonomous systems that include UAVs, ISR, cyber and maritime security. The budget for this program is €590 million from 2017 until 2020, , and then €13 billion from 2021 until 20217.

Unfortunately, with Europe's far less advanced high-tech technology startup culture, this funding is expected to go to the traditional European defense players. While more defense spending by the EU is certainly a good thing, the EU program simply does not incentivize or unleash European commercial high-tech innovation.

It's clear that there is an emerging awareness in the US and with its Allies that the high-tech commercial base has to better compete in a highly challenging, multi-polar world.

To quote ***David Lloyd George***, "*Don't be afraid to take a big step if one is indicated. You can't cross a chasm in two, small jumps.*"

Unfortunately, compared to the Chinese threat, many of the efforts listed above are too small, conform too much to existing traditional government procurement practices and don't engage the power of the small tech innovators.

Yes, they are attracting new companies to the field, and this is certainly a positive step. However, there should be more "*leaps*" from TR-X to TR-9.

In this, the US DIU and UK IOD satellite programs stand out... they should be emulated.

On a recent panel discussion as part of DGI 2020 where Horizon Technologies recently participated, Dr. Vici used a fitting historical example for the way forward in harnessing technology via public/private partnerships. He cited the UK wartime program to crack the German Enigma encryption devices (themselves, ironically, a commercial product developed outside the 1920's Reichsmarine procurement channels) during World War 2. The UK government went outside their normal MoD channels to recruit all sorts of people "*outside the system*" (civilian crossword puzzle experts, Oxford dons, chess masters etc.) who helped to crack German Enigma messages. This is the same spirit that is needed today; using non-traditional personnel and methods for military gain.

A broader historical example is US President ***Franklin Roosevelt*** who, against tremendous bureaucratic resistance, appointed ***Bill Knudsen*** from General Motors to go outside of the War Department and head up military/defense production in 1940 before America entered the Second World War.

In simple terms, the US used its world-leading commercial production techniques and applied them to military/industrial procurement on a massive scale. The US Navy could never have built "*Liberty Ships*" on such a vast scale, and so quickly, without private industry taking the lead; an example of public/private partnership at its finest.

With the Chinese tech threat increasing, it is imperative that the United States, the UK and the West find development and procurement models that harness the innovation and agility of small commercial companies and allow them to leapfrog technologies to keep us at the forefront of this technological race.

The only way to manage this is via Public/Private partnerships under a model that allows private industry to offer dual-use technologies to the military, while retaining their IP and their commercial rights.

In the end, I'm convinced "*High tech capitalism*" will beat state-targeted technology development, technology theft,and spying.

horizontechnologies.eu

John Beckner is the CEO of UK-based Horizon Technologies. Horizon Technologies is under contract to launch the UK's first SIGINT cubesat constellation, Amber, as part of a public/private partnership sponsored by the UK Government.

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SMALL TACTICAL TERMINALS CONNECT PARTNERS

By Kim Hampson, Marketing Director, Viasat Government Systems

The U.S. Navy's decision to award a sole-source contract for KOR-24A Small Tactical Terminals is not just a win for Viasat.

This contract also reflects the desire of the U.S. and its partners to create a Link 16-based communications system that will enable diverse forces and platforms to share real-time data and situational awareness information in a coalition interoperable fashion.

Under a recent Naval Information Warfare Systems Command indefinite delivery/indefinite quantity (ID/IQ) contract, Viasat will provide its KOR-24A Small Tactical Terminals (STT) to foreign military customers.

The KOR-24A STT is the world's only radio that is multi-channel, small form factor and Link 16-capable. More than 1,600 KOR-24As are used by the U.S. military, as well as international partners, to connect helicopter, ground vehicles, small boats, and other "Size, Weight, and Power" (SWaP) constrained platforms.

Viasat is particularly well-suited for satisfying an ID/IQ contract, which is designed to avoid cumbersome processes and timelines that weigh down typical defense contracts.

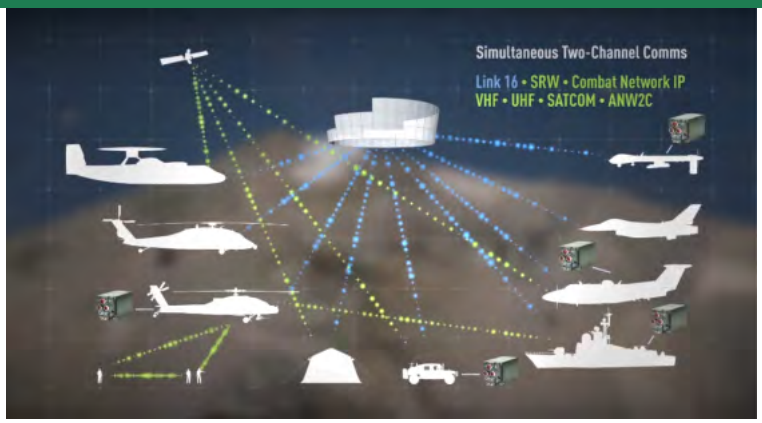
While Viasat has deep roots in defense, the company is accustomed to fulfilling orders rapidly due to its agile business practices and commercial development models.

Andy Kessler

"*We generally look to deliver against an order within 15 to 30 days, which is highly valuable when procuring entities are used to having to wait nine to 12 months*," said ***Andy Kessler***, Vice President and Business Area Director for Viasat's Next Generation Tactical Data Links business.

Kessler believes that the current international percentage of sales at approximately 10 percent will dramatically expand under the Navy contract as overall STT sales grow.

"*We expect the long-term state to be 25 to 30 percent of total sales*," he stated, notwithstanding the fact that U.S. sales are expected to continue to accelerate rapidly, as well.



Interoperability and Flexibility

Kessler attributes foreign interest in the KOR-24A STTs to several factors. One is a desire for interoperability between U.S. and coalition forces, and between coalition forces themselves. Another is the success achieved by the U.S. military using STT equipment.

"*They see what U.S. forces are doing, and they want the same capability*," he said. "*For example, international customers with tactical helicopters want the same capabilities that the U.S. Army has with its Apache helicopters, among others.*"

A particularly important feature of the KOR-24A for international customers is that it can be installed on U.S. and non-U.S. platforms (aircraft, helicopters, vehicles, ships and unmanned systems).

"*We are integrated into a number of coalition platforms already*," Kessler said. "*It is one of the most widely proliferated terminals in terms of SWaP-constrained platforms. It was designed for ease of platform integration.*"

Whether the platform is U.S. or not, the STT offers numerous advantages. Perhaps most important is that the device has a very low SWaP.

Most international customers have Multifunctional Information Distribution System (MIDS) terminals on their larger aircraft, such as fighters and transports.

"*But they have never had an opportunity to integrate a radio that is small enough to go on a platform that cannot afford the SWaP of a MIDS terminal while retaining other waveform functionalities*," Kessler pointed out.

That's where the low SWaP of the STT — which only weighs about 15 pounds — comes in. Also key is the two-channel capability of the KOR-24A, which functions as a Link 16 network device and an additional software-defined tactical radio.

"*For a platform that is upgrading, there is generally not a lot of open space*," Kessler said. "*Normally, if you want to add this capability, you have to take something else off. One of the critical value-propositions of the STT is that if you remove a legacy radio and install an STT, then not only do you have Link 16, but you don't lose the legacy waveforms. Those are all available on the STT's second channel.*"

Because the radio is software-defined, new features and capabilities can be added via software-only upgrades. This, Kessler said, is especially important for international customers that do not want to have to return their terminals to the U.S. for upgrades.

"*Not only are you preserving multifunctionality, but you are doing it at roughly a third to a quarter of the SWaP of the existing MIDS terminals*," he noted. "*That capability is extremely valuable to our international customers.*"

The Naval Information Warfare Systems Command contract further demonstrates the value of Viasat's agile business processes and commercial development models.

"*We're looking forward to continuing to rapidly deliver game-changing technology capabilities like the STT to coalition military forces*," Kessler said.

Edge operators gain real-time combat communications and interoperability to whichever networks suit the mission, with the two-channel, software–defined Small Tactical Terminal from Viasat and Harris. The low–SWaP STT enables helicopters, ground vehicles, and other platforms to switch waveforms and network connections on the fly, merging disparate networks and delivering situational awareness to edge operators as the mission unfolds.

The STT (KOR-24A) is a two-channel radio designed to meet the needs of users who have size, weight, and power constraints but need the information available on Link 16 networks and tactical VHF/UHF. Tactical warfighters, including ground vehicles, helicopters, UAVs, small boats, and light ISR aircraft can now have simultaneous access to Link 16 and either wideband UHF or legacy VHF/UHF. This terminal is packaged in an affordable, industry standard compact form factor and is ruggedized to meet demanding environmental requirements.

With this terminal, edge users have access to both air and ground (friendly and enemy) situation data and can provide secure and reliable target data to the network. With the UHF channel configured for S-TADIL J or JRE, users have a single terminal that provides both LOS and BLOS TADIL J connectivity.

Visit the Viasat ***infosite*** to learn more about the advantages of Viasat's Small Tactical Terminal for foreign military users.

*Note: *SRW and ANW2C waveforms available by U.S. government approval only, limited to nations approved for each waveform.*

Author Kim Hampson, is Viasat Government Systems' Marketing Director.

HEIGHTENING PERFORMANCE, SECURITY AND RESILIENCY FOR DATA-INTENSIVE CRITICAL COMMS

By Aviv Ronai, Vice President, Marketing and Product, NOVELSAT

The military, defense, security and emergency organizations rely on satellite communications (SATCOM) for their operations. Mission critical data and video connectivity is used for fixed communications, Communications-at-the-Halt (CATH), Communications-on-the-Pause (COTP), Communications-on-the-Move (COTM), aero (manned and unmanned), maritime, intelligence, Earth Observation (EO), weapon control, emergency and public safety applications.

Cyber threats against satellite communication have rapidly escalated during the last few years and will continue to advance in capabilities in the foreseeable future, as adversaries are working to intercept, exploit, degrade and deny communications capabilities.

With growing cybersecurity concerns, government organizations, agencies and bodies, as well as commercial integrators and contractors serving the government sector, require comprehensive SATCOM capabilities that can effectively mitigate such threats and reliably operate in contested, degraded and operationally-limited (CDO) environments.

NOVELSAT empowers mission critical SATCOM with the solutions and technologies that are necessary to face the future with confidence.

The company's comprehensive systems capabilities provide an operationally secure, resilient, and effective satellite connectivity to support all forces and responders in carrying out their crucial missions.

Designed to deliver the highest levels of transmission security, robustness and resiliency, NOVELSAT offers comprehensive solutions to meet the growing applications and requirements of mission critical SATCOM. Securing the content, protecting the transmission and preventing interception, the firm's comprehensive solutions provide a wide-ranging security suite that encompasses the functionalities and capabilities for communication security (COMSEC), transmission security (TRANSEC) and interference/jamming mitigation.

NOVELSAT has been at the forefront of satellite content connectivity technology and services for more than a decade and continues to be an innovator and developer of new satellite content connectivity technologies. The firm's leadership foundations are built around proprietary waveform and premier receiver architectures that enable NOVELSAT to provide high-performance satellite transmission and space segment efficiency as well as greater resiliency and robustness.

Pioneering, expanding and enhancing end-to-end capabilities, the company presents best-in industry transmission and content security as well as the unique integration of cutting-edge video capabilities.

NOVELSAT is keenly focused on three key areas — performance, security and video — to address the growing need for higher data rates and extensive protection.

Boosting Performance Transmission

NOVELSAT NS4™, the most bandwidth-efficient waveform, boosts satellite transmission throughput and delivers more bits per Hz compared with any standard available, delivering up to 60 percent higher data rate than DVB-S2 systems and as much as 30 percent higher data rate than DVB-S2X systems.

Adding full bandwidth reuse allows full data rate doubling with lossless uplink and downlink on the same frequency band, driving spectral efficiency over 10 bit/Hz.

A topnotch receiver architecture enhances transmission robustness and flexibility and delivers very high Phase-Noise resiliency, high Doppler shift and rate resiliency as well as industry leading receiver sensitivity and very fast satellite/station handover, with frequency lock time of 1 mSec or less.

These capabilities enable seamless connectivity everywhere, under any condition, providing higher performance, availability and coverage, for demanding deployments such as poles areas, harsh weather conditions, mobility platforms (airborne, maritime, vehicles) as well as for challenging GEO, LEO and inclined orbits use cases.

Heightening Transmission Security & Robustness

NOVELSAT secured communications use COMSEC, TRANSEC and interference/jamming mitigation technologies to provide cyber, link and operational security for satellite connectivity.

The firm's advanced multi-layer encryption assures data security by employing AES 256-bit encryption for full traffic encryption of payload, header and signaling.

A GPG (RSA-2048) encryption is then used to encrypt the AES keys and then to encrypt again the GPG keys.

The multi-layer encryption is complemented with a unique management tool that automatically performs dynamic key generation, over the-air (OTA) distribution, sites authentication, service validation and content entitlement.

For restricting system access and protect remote and on-prem management connectivity, extensive secured management sessions are provided, including encrypted HTTPS for web user interface, encrypted SSH (Secure Shell) for Command Line Interface (CLI) and encrypted SNMPv3.

High interference and jamming resiliency are achieved with a set of advanced detection mechanisms and mitigation algorithms, on top of the built-in (waveform and receiver) resiliency to interference and to other signal-disrupting impediment.

These capabilities excise narrowband, wideband and radar interferences as well as provides high resiliency to satellite blinding with dynamic saturation elimination. In addition, the use of a proprietary waveform elevates technical and operational barriers to adversaries.

Low Probability of Detection/Interception (LPD/LPI) are key capabilities required to protect against adversaries who try to obtain information through monitoring and analysis of the satellite transmission.

To mask any communications activity, NOVELSAT has implemented several solutions. Advanced carrier concealment, against hostile interception, is enabled by carrier echo cancellation and below noise level transmission and advanced traffic concealment, against hostile traffic variation analysis, is enabled by masking channel activity with dummy/idle data. In addition, traffic reception only at paired sites (uplink-downlink) is ensured by employing active, all digital, cancellation of locally-generated echo.

Integrating High Efficiency Video Encoding/Decoding/Transcoding

NOVELSAT boosts video transmission for mission critical applications with unique integration of cutting-edge video capabilities. Converting any video format or delivery standard to higher efficiency video coding enables to deliver more video streams and higher quality over a satellite channel.

Using highest efficiency video coding (HEVC) in conjunction with NOVELSAT NS4™ delivers unparalleled video data rates and efficiency, enabling up to 4 times more video content compared to MPEG4 with DVB-S2.

The optimized, all-in-one integration uniquely combines video encoding/decoding/transcoding, satellite transmission and comprehensive video security.

The advanced multi-layer encryption described above is enhanced with content entitlement, scheduling and blanking for multi-user and multi-privilege environments as well as supports watermarking for identifying leakage or breach.

Create Your Own Proprietary System

Enabling organizations to introduce their own proprietary transmission and functionality is an important element for further enhancing security and protection. NOVELSAT has designed unique capabilities to allow flexible customization. A dedicated customer programable System on Module (SOM) provides customers full control over a second CPU, enabling user defined software, API, GUI and functionality. In addition, unique transparent mode enables customers to work with their proprietary satellite transmission and uniquely define baseband payload structure and ACM algorithm.

Enhance and Protect

NOVELSAT is applying all these technologies and capabilities to enhance and protect data-intensive mission critical communications from intentional or unintentional interferences and threats. The high-performance solutions improve security, resiliency and robustness, as well as increase data rates, availability and coverage, enabling government customers to deliver on their mission. Already in deployment by leading government's organizations and contractors, our technology helps our customers to meet their current and future challenges and makes their networks safe.

Addressing A Wide Range of Use Cases

Quadrupled Video Rates for VISINT Gathering (ISR) and Distribution

The improvements in sensor quality, the growing number of sensors on-board ISR platforms, and the need to distribute these live video feeds to multiple forces and authorities, mandates much higher transmission rates for video content.

To meet the required transmission rates without increasing satellite bandwidth, NOVELSAT provides an innovative all-in-one solution to delivers unparalleled video transmission capacity. Integrating high efficiency video coding (HEVC) and high efficiency transmission waveforms (NS4 or DVB-S2X) enables to deliver up to 4 times more video content for mission critical operations.

Adaptive Earth Observation Connectivity for Greater Download Speeds

The evolution of EO resolution and capabilities results in growing information collection which requires greater download speeds. Working with leading EO satellites, NOVELSAT high performance terminals delivers higher download volume per satellite pass coupled with high transmission robustness.

Using adaptive return channel for EO satellites, NOVELSAT terminals enables ACM operation and improved link margin to deliver higher data rates.

Transparent Cloud Connectivity Solution for IoT and Data Operations

More and more data from satellites is being sent to big cloud networks including imagery, sensing, monitoring, IoT and data transfer, making satellite data easier to access and process. Addressing data cloud connectivity, NovelSat pioneers open and flexible NFV-based cloud connectivity solution. Employing unique transparent mode, NOVELSAT solution enable virtualized connectivity agnostic to satellite transmission standards and proprietary implementations, streamlining data cloud satellite connectivity.

SIGINT Receivers on a Card for Intelligence Gathering

In an era of growing threats, intercepting satellite communications allow governments to enhance their national security. Enabling information interception and gathering, NovelSat offers high sensitivity PCIe-based SIGINT receiver cards, enabling easy integration into any PC-based platform. Agnostic to system vendor, air frame mapping method, payload encryption and ACM mechanism, NovelSat's SIGINT receiver cards capture DVB-S2 and DVB-S2X satellite communications and stream raw data for traffic analysis.

www.novelsat.com

Aviv Ronai is the VP of marketing and product at NovelSat, a leading provider of next-generation content connectivity solutions for satellite communications. Aviv is responsible for building NovelSat's exceptional vision and brand, as well as formulating the company's technological and strategic directions

Recent News: NovelSat Solutions

Sometimes a motivator, something that you have to do to comply with company or government standards, turns out to be to your benefit. And this would seem to be the case for VRT (Vlaamse Radio- en Televisieomroeporganisatie), Belgium's national public-service broadcaster for the Flemish Region and Community. VRT needed to comply with the Belgium government's new regulation requiring CID insertion in satellite signals, that refers to a unique ID that is injected into video or data transmissions by a satellite modulator or modem so that an interfering carrier can be easily identified to enable quick resolution of interference situations.

NovelSat's solution, together with VP Media Solutions, a major Belgium reseller of broadcast solutions and services, includes NS3000 Professional Satellite Modems, with configurations supporting Carrier in Carrier (Carrier Eco Cancellation) and Dual Channel (ASI+IP) capability, all with built-in TCP Acceleration. The NovelSat modem offers 5 percent RoF with the DVB-S2 and S2X standard, and as low as 2 percent RoF with the NovelSat NS4 satellite waveform. These and other features make the NovelSat NS3000 a bandwidth-efficient modem.

VRT broadcast services include contribution, DTH channels, and radio, all via satellite and a fiber network, across Belgium and parts of The Netherlands and Luxembourg. They approached NovelSat with a request to replace their ground station links and contribution SNG transmission equipment. VRT had been transmitting using the outdated DVB-S2 satellite transmission standard with 20-35 percent RoF (Roll-off Factor).

Gary Drutin, NovelSat CEO said the NovelSat broadcast solution for VRT meets the customer's needs for greater efficiency, bi-directional video and data transmission, CID insertion and more.

NOVELSAT is also collaborating with Gilat Telecom for quick restoration of internet connectivity following the West Africa Cable System (WACS) undersea cable cut. The severe cable damage caused internet downtimes and slow speeds that affected all internet providers in the Democratic Republic of Congo (DRC). Using NOVELSAT's high capacity connectivity solutions, Gilat Telecom was able to quickly restore connectivity, providing its MNO and ISP customers a resilient and stable satellite network with nearly uninterrupted service and better customer experience.

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SPACE THREAT ASSESSMENT 2020 (PART ONE)

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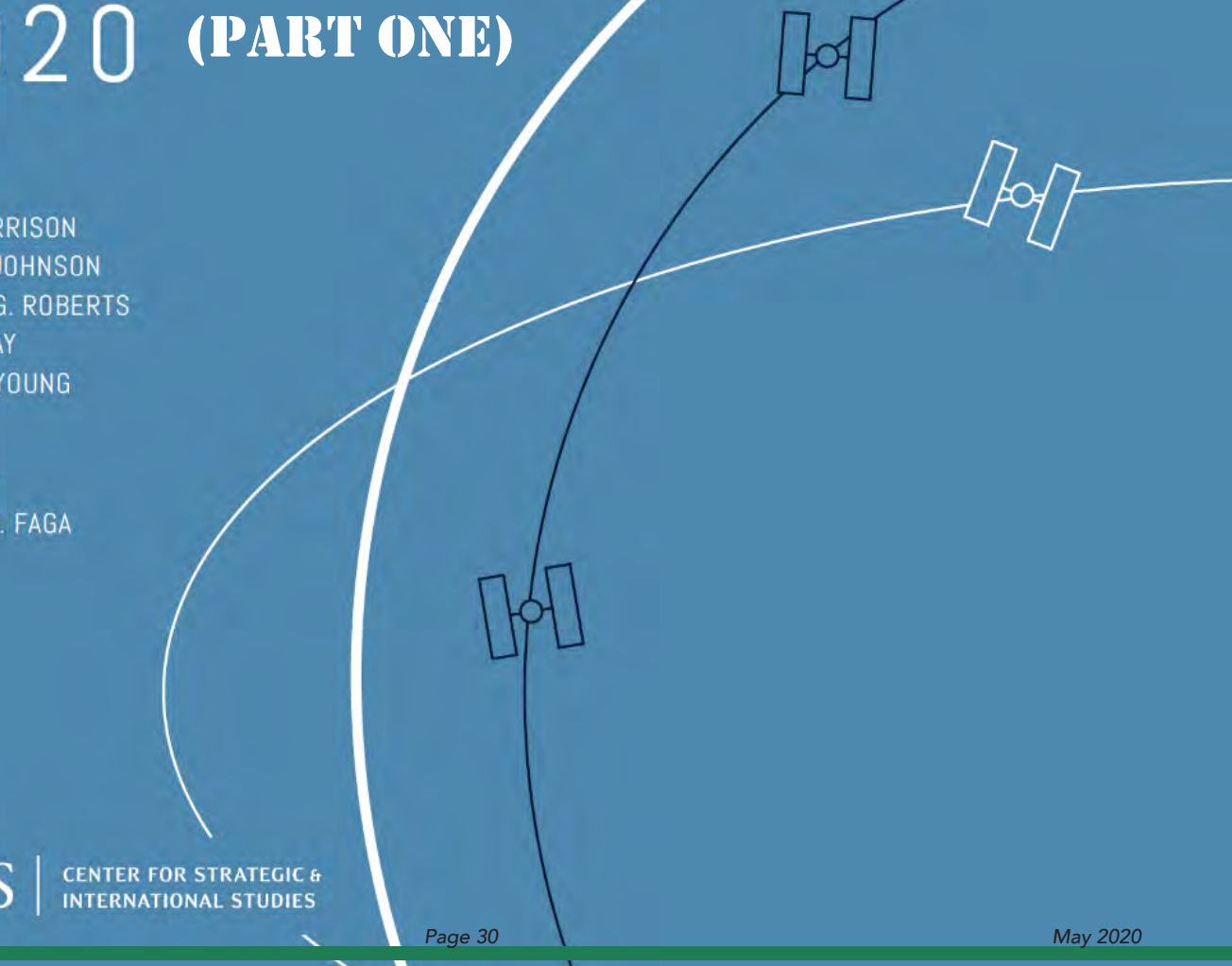

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FOREWORD

MUCH IS SAID THESE DAYS about the possibility of conflict in space during, before, or perhaps, instead of conflict on land, at sea, or in the air. Why is this the case?

The subject is discussed as though it emerged in the last 13 years since the Chinese demonstration of a kinetic ASAT in 2007. In fact, the United States was concerned in 1957 that Sputnik represented a precursor to space-based nuclear weapons. An ASAT program started in the United States in 1958, and the Soviets did similarly. Both superpowers deployed several ASAT systems and performed orbital tests.

Nonetheless, fear on both sides of a serious threat of conflict in space did not emerge until recently. Both the Soviets and the United States understood that the satellites of "National Technical Means" were stabilizing and were keys to de-escalation should a conflict occur. This view changed after the First Gulf War, when space systems moved from being primarily strategic systems to tactical ones providing near real-time support to tactical forces. By that time, the satellites of the Department of Defense and of the Intelligence Community operated and reported almost instantly, and the military services developed the equipment and techniques to acquire, analyze, and distribute space system information very quickly.

Following the First Gulf War, a Russian analysis of the rapid American success noted the efficacy of precision weapons and real-time intelligence. Much of this capability depended on space systems and spurred the Russians and Chinese to a sustained program to develop ASAT capabilities--not only those for physical attack but cyber and electronic attacks as well. In recent years, we have read Russian and Chinese doctrine explaining the importance of ASAT capabilities, and we have seen systems deployed to carry them out.

The situation we confront today was inevitable. Capability is always met with counter-capability. In recognition of this need to defend and to increase our space power in the face of such threats, the United States has wisely created the Space Force and the U.S. Space Command. This is where the people who will design, build, and operate our military space systems reside and where personnel will be trained, careers managed, doctrine developed, and a myriad other elements of a military force undertaken.

Several years ago, an Army general gave a speech where he said, "every company commander depends on space, and takes it for granted." What a challenge for our Space Force and Space Command to assure that our military is served at every level of command without failing.

MARTIN C. FAGA

Former Assistant Secretary of the Air Force for Space and Director of the National Reconnaissance Office

INTRODUCTION

THE PAST YEAR WAS A TRANSFORMATIONAL ONE for space policy in several respects. On December 20, 2019, President Trump signed into law the National Defense Authorization Act for Fiscal Year 2020, creating the Space Force and ushering in what is arguably the most significant reorganization of the U.S. military since the Goldwater Nichols Act of 1986. While the newly created Space Force is responsible for organizing, training, and equipping space forces for the U.S. military, the newly re-established United States Space Command is the geographic combatant command responsible for space operations.

France also made significant organizational changes in 2019 with the issuance of its Space Defense Strategy. It calls for the creation of a Space Command within the Air Force and the renaming of the Air Force to the Air and Space Force. The French defense minister publicly stated that France would develop space control capabilities and active defenses, such as small bodyguard satellites and space-based laser defenses to protect important space assets.

Other countries continue to develop and test counterspace capabilities and conduct suspicious or threatening activities in space. India became the fourth country to successfully test a direct-ascent anti-satellite (ASAT) missile, as well as the only country to conduct a debris-producing test since 2008. Russia continued its co-orbital activities in geostationary orbit (GEO) and caught the attention of many in the space community with its proximity operations around a classified U.S. government satellite in low Earth orbit (LEO).

In commercial space, both SpaceX and OneWeb began deployment of mega constellations in LEO to deliver high-speed internet access globally. OneWeb launched its first set of six satellites in February 2019, and SpaceX launched its first batch of 60 satellites in May 2019. Both companies have conducted additional launches since then, with SpaceX beginning to deploy at a steady pace in early 2020. As of February 17, 2020, SpaceX has launched a total of 302 Starlink satellites, 297 of which are operational. In comparison, the total number of operational satellites in LEO was roughly 1,500 in 2019—a number that could double by the end of 2020. These commercial developments present both opportunities and challenges in what is already a diverse, disruptive, disordered, and dangerous space environment.

The purpose of this annual report from the CSIS Aerospace Security Project is to aggregate and analyze publicly available information on the counterspace capabilities of other nations. It is intended to raise awareness and understanding of the threats, debunk myths and misinformation, and highlight areas in which senior leaders and policymakers should focus more attention. While the report focuses on the capabilities of China, Russia, Iran, North Korea, and India, this year's report places relatively more emphasis than previous years on the counterspace capabilities of select other countries, including some allies and partners of the United States.

This report is not a comprehensive assessment of all foreign counterspace capabilities because much of the information on what other countries are doing is not publicly available. The information in this report is current as of February 22, 2020.

TYPES OF COUNTERSPACE WEAPONS

SPACE IS AN INCREASINGLY IMPORTANT ENABLER of economic and military power. The December 2017 United States National Security Strategy prioritizes maintaining U.S. leadership and freedom of action in this critical domain, but it notes that:

> *Many countries are purchasing satellites to support their own strategic military activities. Others believe that the ability to attack space assets offers an asymmetric advantage and as a result, are pursuing a range of anti-satellite (ASAT) weapons. The United States considers unfettered access to and freedom to operate in space to be a vital interest. Any harmful interference with or an attack upon critical components of our space architecture that directly affects this vital U.S. interest will be met with a deliberate response at a time, place, manner, and domain of our choosing.*[1]

Counterspace weapons vary in the types of effects they create, and the level of technological sophistication and resources required to develop and field them. They also differ in how they are employed and how difficult they are to detect and attribute. The effects of these weapons can be temporary or permanent, depending on the type of system and how it is used. The country-by-country assessments that follow this section group counterspace weapons into four broad categories: kinetic physical, non-kinetic physical, electronic, and cyber.

Illustration A ballistic missile can be used as a kinetic physical counterspace weapon.

KINETIC PHYSICAL

KINETIC PHYSICAL COUNTERSPACE weapons attempt to strike directly or detonate a warhead near a satellite or ground station. A direct-ascent ASAT weapon attempts to strike a satellite using a trajectory that intersects the target satellite without placing the interceptor into orbit. Ballistic missiles and missile defense interceptors can be modified to act as direct-ascent ASAT weapons provided they have sufficient energy to reach the target satellite's orbit. A co-orbital ASAT weapon differs from a direct-ascent weapon because it is first placed into orbit. When commanded, the satellite then maneuvers to strike its target. Co-orbital ASATs can remain dormant in orbit for days or even years before being activated. A key technology needed to make both direct-ascent and co-orbital ASAT weapons effective is the ability to detect, track, and guide the interceptor into a target satellite. An onboard guidance system requires a relatively high level of technological sophistication and significant resources to test and deploy.[2]

Ground stations are vulnerable to kinetic physical attacks by a variety of conventional military weapons, from guided missiles and rockets at longer ranges to small arms fire at shorter ranges. Because they are often highly visible, located outside of the United States, and are more accessible than objects in space, ground stations can be an easier target for adversaries seeking to disrupt or degrade space systems. Even if the ground stations themselves are difficult to attack directly, they can be disrupted indirectly by attacking the electrical power grid, water supply, and the high-capacity communications lines that support them.

Kinetic physical attacks generally have irreversible effects on the satellites and ground stations targeted. These counterspace weapons are likely to be attributable because the United States and others can identify the source of a direct-ascent ASAT launch or ground attack and can, in theory, trace a co-orbital ASAT's orbital data back to its initial deployment. In both cases, the attacker is likely to know whether its attack is successful almost immediately because the effects would be publicly visible through orbital debris or a damaged ground station.

NON-KINETIC PHYSICAL

NON-KINETIC COUNTERSPACE weapons, such as lasers, high-powered microwave (HPM) weapons, and electromagnetic pulse (EMP) weapons, can have physical effects on satellites and ground stations without making physical contact. These attacks operate at the speed of light and, in some cases, can be less visible to third-party observers and more difficult to attribute.

High-powered lasers can be used to damage or degrade sensitive satellite components, such as solar arrays. Lasers can also be used to temporarily dazzle or permanently blind mission-critical sensors on satellites. Targeting a satellite from Earth with a laser requires high beam quality, adaptive optics, and advanced pointing control to steer the laser beam as it is transmitted through the atmosphere—technology that is costly and requires a high degree of sophistication.[3] A laser can be effective against a sensor on a satellite if it is within the field of view of the sensor, making it possible to attribute the attack to its approximate geographical origin. The attacker, however, will have limited ability to know if the attack was successful because it would not likely produce debris or other visible indicators.

An HPM weapon can be used to disrupt a satellite's electronics, corrupt data stored in memory, cause processors to restart, and, at higher

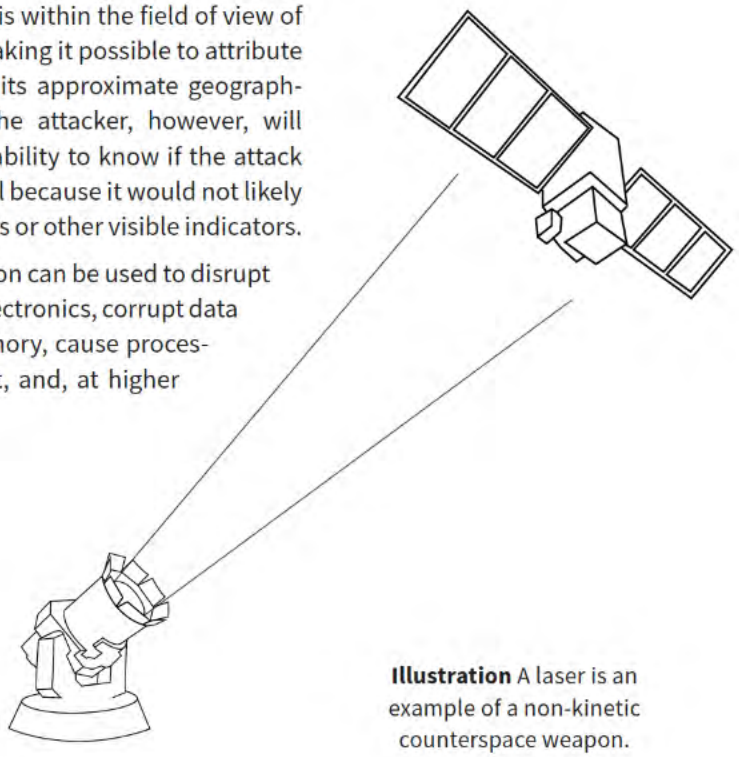

Illustration A laser is an example of a non-kinetic counterspace weapon.

power levels, cause permanent damage to electrical circuits and processors. A front-door HPM attack uses a satellite's own antennas as an entry path, while a backdoor HPM attack attempts to enter through small seams or gaps around electrical connections and shielding.[4] Because electromagnetic waves disperse and weaken over distance and the atmosphere can interfere with transmission at high power levels, an HPM attack against a satellite is best carried out from another satellite in a similar orbit. Both front-door and back-door HPM attacks can be difficult to attribute to an attacker, and as with a laser weapon, the attacker may not know if the attack has been successful.

The use of a nuclear weapon in space can be an indiscriminate form of non-kinetic physical attack. While a nuclear detonation would have immediate effects for satellites within range of its EMP, it also creates a high radiation environment that accelerates the degradation of satellite components over the long term for unshielded satellites in the affected orbital regime.[5]

ELECTRONIC

ELECTRONIC ATTACKS TARGET the means through which space systems transmit and receive data by jamming or spoofing radio frequency (RF) signals. Jamming is a form of electronic attack that interferes with RF communications by generating noise in the same frequency band and within the field of view of the antenna on the targeted satellite or receiver. An uplink jammer interferes with the signal going from the Earth to a satellite, such as the command and control uplink. Downlink jammers target the signal from a satellite as it propagates down to users on the Earth. User terminals with omnidirectional antennas, such as many GPS receivers and satellite phones, have a wider field of view and thus are susceptible to downlink jamming from a wider range of angles on the ground.[6]

The technology needed to jam many types of satellite signals is commercially available and relatively inexpensive. Jamming is a reversible form of attack because once a jammer is turned off, communications return to normal. Jamming can also be difficult to detect or distinguish from accidental interference, making attribution and awareness more difficult. In 2015, General John Hyten, then-commander of Air Force Space Command, noted that the U.S. military was unintentionally jamming its own communications satellites an average of 23 times per month.[7]

Spoofing is a form of electronic attack where the attacker tricks a receiver into believing a fake signal, produced by the attacker, is the real signal it is trying to receive. Spoofing the downlink from a satellite can be used to inject false or corrupted data into an adversary's communications systems. If an attacker successfully spoofs the command and control uplink signal to a satellite, it could take control of the satellite for nefarious purposes.

Through a type of spoofing called "meaconing," even the encrypted military GPS signals can be spoofed. Meaconing does not require cracking the GPS encryption because it merely rebroadcasts a time-delayed copy of the original signal without decrypting it or altering the data.[8] Like jammers, once a spoofer is developed, it is relatively inexpensive to produce and deploy in large numbers and can be proliferated to other state and non-state actors.

CYBER

UNLIKE ELECTRONIC ATTACKS, which interfere with the transmission of RF signals, cyberattacks target the data itself and the systems that use this data. The antennas on satellites and ground stations, the landlines that connect ground stations to terrestrial networks, and the

Illustration A truck-mounted jammer is a type of electronic counterspace weapon.

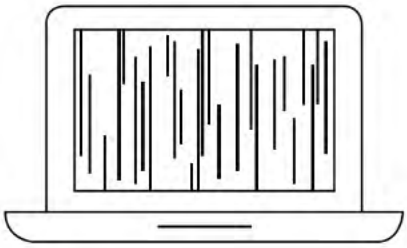

Illustration
Cyberattacks can be used to take control of a satellite and damage or destroy it.

user terminals that connect to satellites are all potential intrusion points for cyberattacks. Cyberattacks can be used to monitor data traffic patterns (i.e., which users are communicating), to monitor the data itself, or to insert false or corrupted data in the system. While cyberattacks require a high degree of understanding of the systems being targeted, they do not necessarily require significant resources to conduct. Cyberattacks can be contracted out to private groups or individuals, which means that a state or non-state actor that lacks internal cyber capabilities may still pose a cyber threat.[9]

A cyberattack on space systems can result in data loss, widespread disruptions, and even permanent loss of a satellite. For example, if an adversary can seize control of a satellite through a cyberattack on its command and control system, the attack could shut down all communications and permanently damage the satellite by expending its propellant supply or damaging its electronics and sensors. Accurate and timely attribution of a cyberattack can be difficult, if not impossible, because attackers can use a variety of methods to conceal their identity, such as using hijacked servers to launch an attack.

THREAT CHARACTERISTICS

The types of counterspace threats described above have distinctly different characteristics that make them more suitable for use in some scenarios than others. As shown in Table 1, some types of counterspace threats are difficult to attribute or have fully reversible effects, such as mobile jammers. High-powered lasers, for example, are "silent" and can carry out an attack with little public awareness that anything has happened. Other types of counterspace weapons produce effects that make it difficult for the attacker to know if the attack was successful, and some produce collateral damage that can affect space systems other than the one being targeted.

Counterspace weapons that are reversible, difficult to attribute, and have limited public awareness are ideally suited for situations in which an opponent may want to signal resolve, create uncertainty in the mind of its opponent, or achieve a fait accompli without triggering an escalatory response. For example, an adversary that wants to deter the United States from intervening in a situation may believe that such attacks will stay below the threshold for escalation (i.e., not trigger the very thing it is trying to prevent) while creating significant operational challenges for the United States that make the prospect of intervention more costly and protracted. Conversely, counterspace weapons that have limited battle damage assessment or that risk collateral damage may be less useful to adversaries in many situations. Without reliable battle damage assessment, for example, an adversary cannot plan operations with the confidence that its counterspace actions have been successful. Furthermore, weapons that produce collateral damage in space, such as large amounts of space debris, run the risk of escalating a conflict and turning other nations against the attacker.

Table 1

TYPES OF COUNTERSPACE WEAPONS

	Kinetic Physical			Non-Kinetic Physical			
Types of Attack	Ground Station Attack	Direct-Ascent ASAT	Co-Orbital ASAT	High Altitude Nuclear Detonation	High-Powered Laser	Laser Dazzling or Blinding	High-Powered Microwave
Attribution	Variable attribution, depending on mode of attack	Launch site can be attributed	Can be attributed by tracking previously known oribt	Launch site can be attributed	Limited attribution	Clear attribution of the laser's location at the time of attack	Limited attribution
Reversibility	Irreversible	Irreversible	Irreversible or reversible depending on capabilities	Irreversible	Irreversible	Reversible or irreversible; attacker may or may not be able to control	Reversible or irreversible; attacker may or may not be able to control
Awareness	May or may not be publicly known	Publicly known depending on trajectory	May or may not be publicly known	Publicly known	Only satellite operator will be aware	Only satellite operator will be aware	Only satellite operator will be aware
Attacker Damage Assessment	Near real-time confirmation of success	Near real-time confirmation of success	Near real-time confirmation of success	Near real-time confirmation of success	Limited confirmation of success if satellite begins to drift uncontrolled	No confirmation of success	Limited confirmation of success if satellite begins to drift uncontrolled
Collateral Damage	Station may control multiple satellites; potential for loss of life	Orbital debris could affect other satellites in similar orbits	May or may not produce orbital debris	Higher radiation levels in orbit would persist for months or years	Could leave target satellite disabled and uncontrollable	None	Could leave target satellite disabled and uncontrollable

	Electronic			Cyber		
Types of Attack	Uplink Jamming	Downlink Jamming	Spoofing	Data Interccept or Monitoring	Data Corruption	Seizure of Control
Attribution	Modest attribution depending on mode of attack	Modest attribution depending on mode of attack	Modest attribution depending on mode of attack	Limited or uncertain attribution	Limited or uncertain attribution	Limited or uncertain attribution
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Irreversible or reversible, depending on mode of attack
Awareness	Satellite operator will be aware; may or may not be known to the public	Satellite operator will be aware; may or may not be known to the public	May or may not be known to the public	May or may not be known to the public	Satellite operator will be aware; may or may not be known to the public	Satellite operator will be aware; may or may not be known to the public
Attacker Damage Assessment	No confirmation of success	Limited confirmation of success if monitoring of the local RF environment is possible	Limited confirmation of success if effects are visible	Near-real time confirmation of success	Near-real time confirmation of success	Near-real time confirmation of success
Collateral Damage	Only dirupts the signals targeted and possible adjacent frequencies	Only disrupts the signals targeted and possible adjacent frequencies	Only corrupts the specific RF signals targeted	None	None	Could leave target satellite disabled and uncontrollable

Number of Successful Orbital Launches in 2019[10]

32

CHINA

"No force will stop or shake China or its people from achieving its goals"

PRESIDENT XI JINPING, 2019[11]

IN THE PAST DECADE, China has been barreling toward its lofty space goals. In the 2010s alone, China conducted over 200 successful orbital launches.[12] China's civil, military, and commercial capabilities are rapidly growing, and its 2020 plans show that the country aims to launch over 60 satellites into orbit via 40 launches over the coming year.[13]

China's civil space program is focused on its network of BeiDou positioning, navigation, and timing (PNT) satellites, similar to the U.S. Global Positioning System (GPS). China plans on launching two BeiDou satellites into geostationary orbit (GEO) in 2020 as well as further developing its Gaofen remote sensing satellite constellation. Since early 2019, *Chang'e-4*, the Chinese lunar lander mission that delivered a successful lunar rover called *Yutu-2*, has been conducting an exploration mission on the far side of the Moon. China plans to follow up this mission in late 2020 with *Chang'e-5*, a mission that aims to return samples from the Moon back to Earth for further study. To support its growing space capabilities, China has "built an expansive ground support infrastructure to support its growing on-orbit fleet and related functions including spacecraft and space launch vehicle (SLV) manufacture, launch, C2 [command and control], and data downlink."[14]

China also intends to send a mission to Mars with an orbiter and probe. This mission will include 13 science payloads and is on track for a July 2020 launch.[15] Three different launch vehicles are also scheduled to make their first flight in 2020: the Long March-5B, the Long March-7A, and the Long March-8.

The Long March-5B will be China's heavy-lift workhorse, supporting future exploration missions as well as the planned Chinese Space Station (CSS).[16] The first test launch of the -5B will likely take place in April 2020. If successful, it will be used to launch the first section of the modular CSS. The Long March-8 is planned to be China's first rocket with a reusable first stage and is planned to support China's growing commercial space sector.[17] Furthermore, "China aspires for a 2036 first human mission to the moon."[18]

China is continuing to move forward with a new modular space station. China has successfully operated two previous space labs in LEO, *Tiangong* 1 and *Tiangong* 2, through its Project 921 program, which began in 1992.[20] The new space station will consist of three modules. The core module of the CSS passed final review but is facing possible launch delays. Currently, it is expected to launch in 2020, while the two additional modules are planned for launch between 2022 and 2024.[21] Three or four manned missions and several cargo missions are also planned, but launch delays have caused schedules to slip for the entire program.[22] The station is estimated to have a 10-year lifespan, with the possibility of an extension.[23]

China is also expanding its international cooperation. China hosted a selection process for opportunities to host scientific payloads on the CSS. The final selection was announced in 2019 and includes nine projects, involving "23 institutions from 17 Member States of the United Nations in Asian-pacific, European, African, North American and South American regions."[24] China has furthered its space partnership with Russia through cooperating to develop "Russia's future *Luna-26* lunar orbiter, China's *Chang'e-7* lunar polar lander, and a joint lunar and deep space data center with a hub in each country."[25]

China's busiest launch site, the Xichang Satellite Launch Center, hosted 19 of China's 32 launches in 2019.[26] Located in the south of China, Xichang is currently expanding by adding another launch pad in order to keep pace with China's growing national and commercial launch demands.[27]

After a 2014 decree to allow private companies to develop SLVs, several new nominally private (though typically state-backed) Chinese companies began to develop and test new launch vehicles. China's commercial space companies grew from around 30 in 2017 to over 100 in 2018. This growth has led to the introduction of new commercial policies in 2019 in order to better regulate the growing commercial space launch sector.[29] These regulations have had a relatively positive response from Chinese commercial companies.[30]

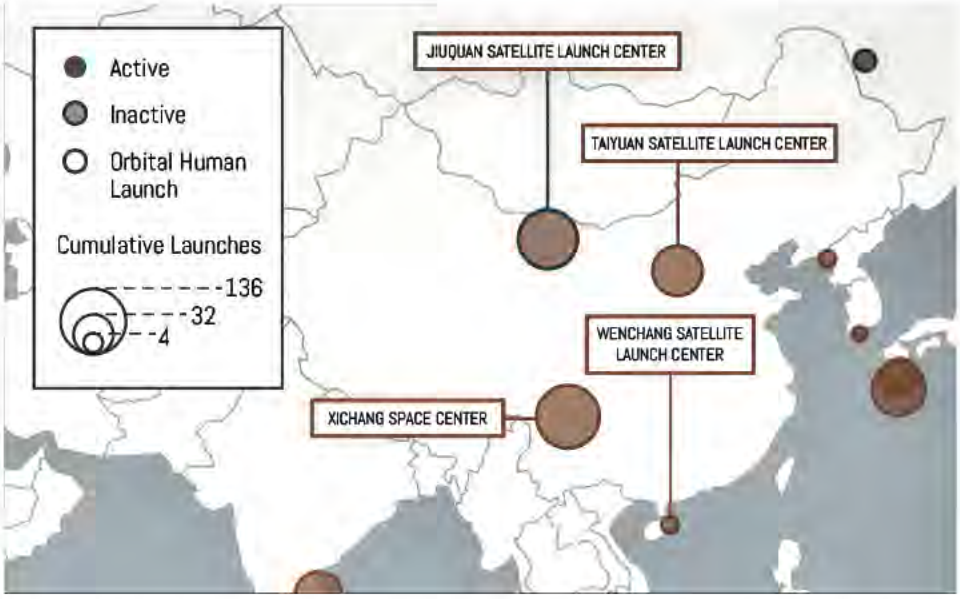

Figure 1: Chinese National Spaceports. China currently has four active spaceports, which have collectively launched hundreds of satellites and several taikonauts, or Chinese astronauts.

SPACE-TRACK.ORG / CSIS AEROSPACE SECURITY[28]

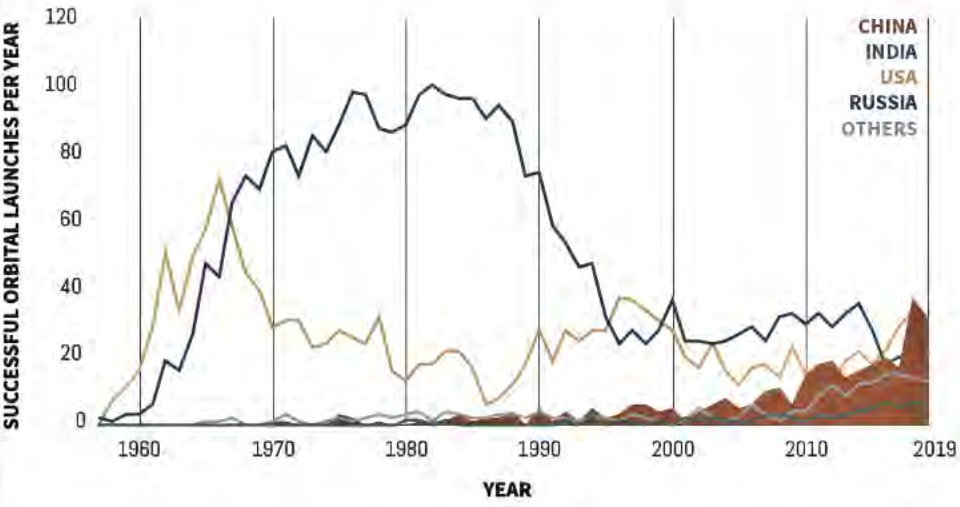

Figure 2: Chinese Orbital Space Launches (1957-2019). China had more successful orbital space launches in 2019 than any other nation.

SPACE-TRACK.ORG / CSIS AEROSPACE SECURITY[19]

SPACE ORGANIZATION AND DOCTRINE

The Chinese government operates separate civil and military space organizations. The China National Space Administration (CNSA) falls within the State Council's State Administration for Science, Technology, and Industry for National Defense (SASTIND) and is the primary organization for China's civil space activities. The main developer of national civil space technologies is the China Aerospace Science and Technology Corporation (CASC), a state-owned aerospace corporation. Meanwhile, military space activities are run through the People's Liberation Army (PLA). However, each of these entities collaborate with one another on developing space technologies.[31]

In July 2019, China released its first official defense white paper since 2015. Prior to this four-year gap, China had released similar white papers about every two years. Analysts acknowledge that the 2019 document "adds little to previous official reports on the details of recent reforms."[32] In line with how China views the space domain, the 2019 white paper references "outer space, electromagnetic space and cyberspace" all as one national defense aim.[33] China established the Strategic Support Force (SSF) in 2015 to bring the management of these strategic areas under one entity. Unlike the United States and even Russia, the PLA appears to view these three domains as inherently intertwined.

There is only one paragraph in the 2019 white paper that focuses solely on the space domain. It touts China's activity in international fora on space-related issues, such as the UN Office for Outer Space Affairs. The white paper recognizes space as of strategic importance to the nation and states that "space security provides strategic assurance for national and social development."[34] This rhetoric is consistent with other statements and posturing that China has demonstrated in recent years.

THE SSF HAS BEGUN TRAINING SPECIALIZED UNITS WITH DIRECT-ASCENT ASAT WEAPONS.

This also builds on the 2015 Chinese white paper, which stated that "outer space and cyberspace have become new commanding heights in strategic competition among all parties."[35] Many scholars interpreted this statement as a formal designation of both space and cyberspace as new warfighting domains.[36] To this end, the PLA founded the SSF to centralize and manage the military's space, cyber, and electronic warfare missions. Before the 2015 reorganization, responsibilities for cyber, space, and electronic warfare were scattered across at least four different PLA departments. The establishment of the SSF indicates the PLA's prioritization of these critical areas of warfare.[37]

In 2018, China published an Outline of Training and Evaluation doctrine, which emphasized joint warfare training between the different military services focused on combating "strong military opponents."[38] For the space domain, this is likely directed against the United States. Originally, the SSF was not assessed to have full control over China's ASAT capabilities. Experts believed that the responsibility for direct-ascent ASATs may lie with either the PLA's Rocket Force, which manages China's nuclear arsenal, or the PLA's Air Force.[39] However, recent records show that the SSF has begun training specialized units with direct-ascent ASAT weapons capable of targeting satellites in LEO.[40]

According to the U.S-China Economic and Security Review Commission, Beijing has "sought to leverage military-civil fusion to commercialize its existing space technology." Utilizing civil or commercial technologies to bolster or disguise its military space systems is a recognizable theme throughout China's counterspace weapons program. "The goal of military-civil fusion in China's space sector is not primarily to develop cutting-edge technology but to produce existing technology that meets most customers' needs at a lower cost and at greater commercial scale and efficiency."[41]

COUNTERSPACE WEAPONS

Kinetic Physical

China has very capable kinetic physical counterspace capabilities and has proven this several times with a range of direct-ascent ASAT weapons tests. Thus far, China's primary focus has been targets in LEO, but recent tests indicate China also has a direct-ascent capability able to reach GEO. It does not appear that China has successfully tested a co-orbital ASAT capability, although it has demonstrated several of the technical capabilities required to construct such a weapon.

> "China continues development of multiple counterspace capabilities designed to degrade and deny adversary use of space-based assets during a crisis or conflict."
>
> U.S. OFFICE OF THE SECRETARY OF DEFENSE [42]

China had its first successful test of a kinetic physical ASAT weapon in 2007, after two previous failed tests.[43] This test of a direct-ascent *SC-19* missile system targeted and destroyed an aging Chinese meteorological satellite, producing over 3,000 trackable pieces of debris in LEO. Around 2,800 trackable pieces of debris from this test remain in orbit, with 11 pieces deorbiting in 2019.[44] This debris threatens the safe operation of hundreds of other satellites in LEO, including the International Space Station (ISS).[45]

China has not conducted a debris-producing direct-ascent ASAT test since 2007. However, analysts believe several other kinetic physical tests—or suspected tests—have occurred since then.[46] These suspected tests have not to date produced orbital debris or threatened any orbiting satellite.[47] Table 2 summarizes several Chinese ASAT, or suspected ASAT, tests. The missile tests are harder to judge because they could also function as a counterspace capability during times of conflict.

China has also developed and launched several satellites which are testing technologies that could be used for co-orbital counterspace capabilities. None of these tests have resulted in a verifiable destructive incident. Primarily, China has been testing its rendezvous and proximity operations (RPO) capabilities, a dual-use technology used to maneuver satellites in orbit near one another. Whether this maneuvering is for nefarious purposes, possibly making it a co-orbital ASAT, or for peaceful purposes, such as for on-orbit servicing or active debris removal missions, is unclear. Distinguishing the intent of the RPO movements is critical to determining whether or not a satellite is

Table 2

DIRECT-ASCENT ASAT OR DUAL-USE TESTS

Type	Year	Weapons System	Comments	Kinetic Impact?
ASAT test	2005	*SC-19*	Failed intercept of target. First recorded test for a direct-ascent ASAT.	No.
ASAT test	2006	*SC-19*	Failed intercept of target.	No.
ASAT test	2007	*SC-19*	Successful intercept of target.	Yes, and created thousands of debris on-orbit.
Missile defense test (suborbital)[48]	2010	*SC-19*	Reported successful technology test against a suborbital target. Likely "an effort to understand the homing performance of the interceptor."[49]	Yes.
Missile defense test (suborbital)	2013	Possibly *SC-19*[50]	Reported successful technology test against a suborbital target. Likely another technology demonstration test.[51]	Yes.
ASAT test	2013	*DN-2*	China declared the test as a high-altitude science mission. U.S. military assessed the test as proof Chinese direct-ascent ASATs could reach targets up to GEO.[52]	No.
ASAT test	2014	*SC-19*[53]	China claimed it was a land-based missile interceptor test, while the United States assessed the test as a non-destructive ASAT test.[54]	No. Possibly done to test timing capabilities.[55]
ASAT test	2015	*DN-3*[56]	China claimed it was a land-based missile interceptor test, while the United States assessed the test as a non-destructive ASAT test.[57]	No.
Missile defense test	2017	*DN-3*	Unsuccessful test of the DN-3 missile interceptor.[58]	No.
Missile defense test	2018	*DN-3*	DN-3 midcourse interceptor successfully intercepted its DF-21 target.[59]	Yes.

a counterspace weapon, but determining intent is almost impossible until a hostile action takes place. According to the U.S.-China Economic and Security Review Commission, "China's testing of RPOs has been similar to past U.S. tests, and no country has criticized RPOs carried out by China as illegal or violating any norm." China, Russia, and the United States all have satellites in GEO performing RPO activities around other satellites in orbit.[60]

"China has engaged in dual-use activities such as rendezvous and proximity operations (RPO)—which demonstrate co-orbital capabilities—that, while not prohibited, create problems for U.S. national security."

U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION[61]

China has been testing these technologies for over a decade. For example, in 2008, a Chinese spacecraft deployed a miniature imaging satellite, the *BX-1*, that was jettisoned from its mother spacecraft. It appears that the satellite was unable to be actively controlled until after it had passed the International Space Station. It is estimated that the uncontrolled satellite came within 25 kilometers of the station. Despite many reports in the United States claiming that this was the first co-orbital ASAT test from China, the maneuver appears to have been unintentional.[62]

SJ-12, a Chinese satellite in LEO, conducted a series of remote proximity maneuvers with an older Chinese satellite, *SJ-06F*, in 2010. The maneuvers appeared to be slow, methodical, and intentional and occurred over several weeks in the summer of 2010.[63] Some have speculated that this mission was designed to test co-orbital jamming or other counterspace capabilities, however this has not been definitively proven in an unclassified setting.[64] At one point, *SJ-12* made contact with *SJ-06F* at low speed; however, this incident was "unlikely to have resulted in debris or significant damage to either satellite."[65] Testing RPO capabilities may have been a test run for the 2011 docking of the Shenzhou space capsule with the *Tiangong-1* space station, but the *SJ-12* maneuver could have serious counterspace implications as well.[66]

China has also been testing satellites with robotic arms, a dual-use technology that could be used as a test bed for docking operations for China's future space station, active debris removal missions, or a co-orbital ASAT. In 2013, China claimed that three new satellites were "conducting scientific experiments on space maintenance technologies."[67] However, U.S. officials reported that the one satellite was equipped with a robotic arm, which tested its ability to grapple and seize another satellite.[68]

Three years later, in 2016, China launched the *Aolong-1* spacecraft, which included a robotic arm and a sub-satellite that would be released and recovered during its mission. According to official statements, the *Aolong-1* was intended to test technologies needed to collect and deorbit space debris. Experts have debated the success of this test.[69]

The South China Morning Post reported in 2019 about recently declassified government documents which showcased how decade-old Chinese satellite technology has provided a base for "the development of new weapon systems powered by artificial intelligence." It is unclear how AI is utilized, but the article reports that the new small satellites can be equipped with robotic arms for active debris-removal missions. This technology is, of course, dual-use and could theoretically be used on a range of objects in orbit. The declassified document states that China has been developing and testing this technology since 2008. Without elaborating further, the document claims that the robotic arm technology has also been incorporated into "drones, smart weapons and robots." The article also claims that these satellites could remain attached to the debris it collects "to avoid being tracked from the ground."[70]

On the same mission as *Aolong-1*, China also deployed the *Tianyuan-1* spacecraft, which according to Chinese press accounts successfully tested the ability to refuel other satellites while in orbit.[71] This test, as well as the Aolong-1 test, received significant media coverage in the United States due to its potential dual-use as ASAT weapons.

While none of China's RPO activities in LEO or GEO appear to have damaged other satellites, these technological advancements in RPO have many experts concerned about China's intent. And unlike Russian RPO activity, China's RPO activities have been primarily focused on other Chinese satellites.

China can also pose a threat to space systems through its ability to attack the ground stations that control satellites

Taking a Break, SJ-17's Lack of Movement

***SJ-17*, A CHINESE SATELLITE** in geostationary orbit known for its unusual behavior, appears to have put a pause on its rendezvous and proximity operations in 2019. Compared to its first two years of operation, when the satellite appears to have performed close approaches and rendezvous operations with four Chinese satellites—*Chinasats 5A, 6A, 20,* and *1C*—the lack of movement in 2019 is notable. According to CSIS analysis, *SJ-17* restarted RPO maneuvers with another Chinese satellite in GEO, *Chinasat 6B*, in late December 2019 and was still in an unusually close orbit in late January 2020. In the past, *SJ-17*'s RPOs have lasted anywhere from a few weeks to over three months.[72] New analysis of *SJ-17*'s on-orbit activity also found that the satellite spent significant time near an Indonesian communications satellite, *Telkom 3S,* in late 2017 and early 2018, but there has been no public statement from Indonesia on *SJ-17*'s maneuvering within 10km of its satellite. In a 2015 paper published in a Chinese research journal, scientists speculated that a small satellite could be used to approach a large satellite in GEO in order to take high-quality pictures and quickly retreat or pass the target satellite to minimize detection.[73] While *SJ-17* is by no means a small satellite, it is possible that China is developing the skills and technology to accomplish such intelligence-gathering missions.[74]

with its conventional forces. China has the largest standing army of any nation, and over the past decade it has significantly increased its military budget and modernized its conventional military forces.[75] In a conflict, China could be capable of striking an adversary's satellite ground stations with ballistic missiles, cruise missiles, or long-range strike aircraft. As China's military reach continues to expand, it will be able to use its conventional forces to hold ground stations at risk over progressively greater distances.

Non-Kinetic Physical

In 2018, then-U.S. Director of National Intelligence Dan Coats assessed that China is making advances in directed-energy technology that can "blind or damage sensitive space-based optical sensors, such as those used for remote sensing or missile defense."[77] While this may sound like a major announcement of Chinese capabilities, China had already demonstrated its ability to dazzle American satellites in the mid-2000s. In 2006, reports surfaced that U.S. imaging satellites were illuminated by lasers over Chinese territory.[78] Then-Director of the National Reconnaissance Office (NRO) Donald Kerr acknowledged that U.S. imagery satellites were dazzled while passing over China but stated that it did not "damage the U.S. satellite's ability to collect information."[79] This incident demonstrates that China had much of the technology necessary to field an operational capability to dazzle

"The [People's Liberation Army] is also deploying directed-energy weapons, and we expect them to field a ground-based laser system aimed at low-orbit space sensors by next year."

THEN-ACTING SECRETARY OF DEFENSE PATRICK SHANAHAN[76]

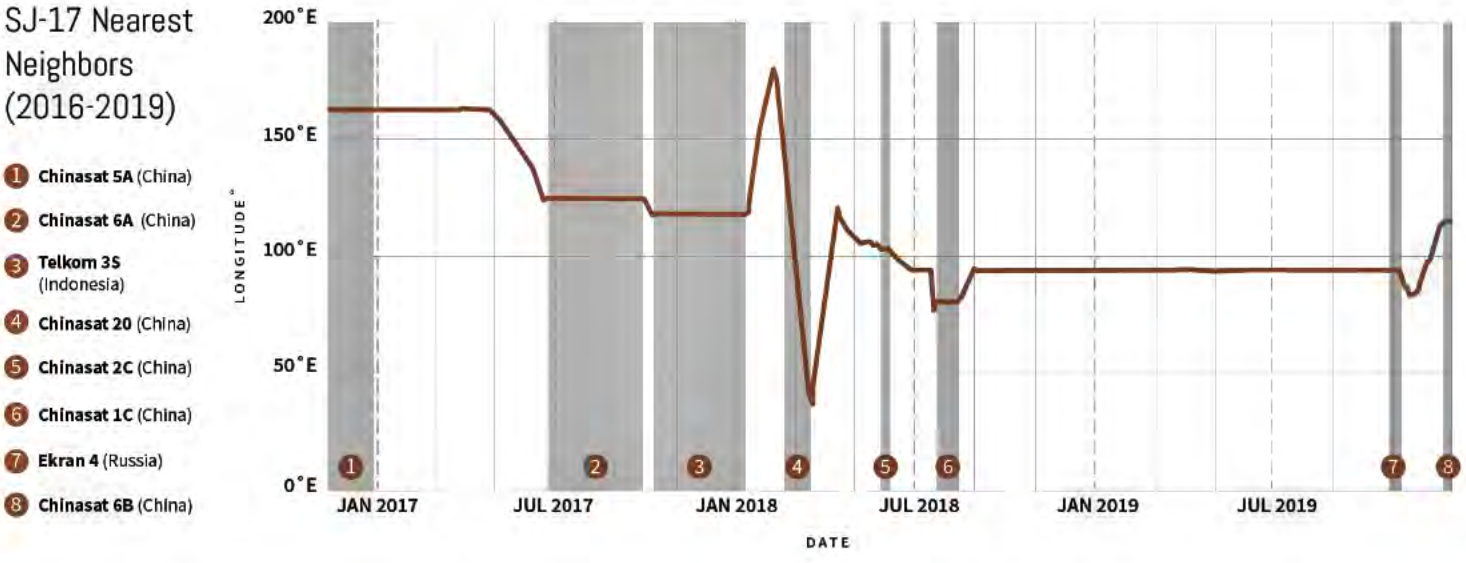

Figure 3: Chinese Rendezvous and Proximity Operations in GEO. Publicly available orbital positioning data suggests that Chinese satellite *SJ-17* has made several close approaches and inspections in GEO. Learn more about SJ-17's behavior, including a list of the satellite's nearest neighbors. at **aerospace.csis.org/SJ17.**

SPACE-TRACK.ORG / CSIS AEROSPACE SECURITY

or blind a satellite back in 2006.[80] Recent statements indicate that China has continued to build and field more capable directed-energy systems. As one China expert highlighted, "the only fundamental barrier to learning these abstract elements [directed-energy] and achieving a practical weapon capability is effort—time, will, and money."[81]

Recently appointed Chief of Space Operations, General John J. Raymond noted in public remarks that, "we're pretty comfortable [in asserting] that they are developing directed energy weapons — probably building lasers to blind our satellites."[82] In early 2019, the Defense Intelligence Agency made a similar claim, stating "China likely is pursuing laser weapons to disrupt, degrade, or damage satellites and their sensors and possibly already has a limited capability to employ laser systems against satellite sensors."[83]

Chinese military and technical writings have often referenced directed-energy weapons as a key technology in a successful counterspace strategy.[84] The SSF is comprised of both Chinese space forces and electronic warfare-focused forces, likely indicating that the PLA sees interoperability between these two areas of warfare. Expert Mark Stokes testified that "The PLASSF Network Systems Department is central to China's counterspace mission." Stokes went on to explain that "Technical articles published . . . suggest the unit, at least in part, is responsible overseeing research, development, and acquisition of electronic counterspace systems." These same units may also be responsible for research and development and testing of high-powered microwave systems.[85]

In 2019, China surprisingly released an announcement alongside images of a new directed-energy system. This Chinese laser gun is reportedly designed to focus on small boats or drones.[86] While not directly a counterspace weapon, some of the technology would likely be similar for a higher-powered system that could affect a satellite in orbit. Furthermore, a top Chinese weapons firm is developing synthetic diamonds, also likely for use in directed-energy weapons. Diamonds can amplify and focus energy outputs to better ensure that the energy beam is intense enough to damage targets.[87]

Satellite imagery analysts speculated in early 2019 that China had been developing significant satellite lasing facilities.[88] Analysts speculate that China is pursuing these efforts in at least five different locations across the country, due to the nature of the buildings and surrounding infrastructure. One image even depicts a suspected electro-magnetic pulse (EMP) simulator suspended between two structures.[89] However, no other analysts appear to have corroborated these assessments.

China also announced an airborne laser in early 2020. While the details were confidential, the titles of two defense procurement bid requests may give insight on the PLA's plans. The two bids request the "procurement plan for airborne laser attack pod" and a "price inquiry on procurement plan for controlling software module of laser attack platform." The system appears to be intended to target other aircraft or missiles, but similar technology could be used to target satellites.[90]

While details from the PLA have been minimal and no public test has occurred on orbit, China has also shown interest in developing HPM weapons for air and missile defense. In January 2017, Chinese media celebrated the work of expert Huang Wenhua, who developed a miniaturized HPM weapon capable of being placed on a ship.[91] However, adding a mobile HPM system to a satellite would require further reductions in size, weight, and power in addition to a number of other integration challenges unique to the space environment.

As a nuclear power with intercontinental ballistic missiles (ICBMs), China also has the latent capability to launch a nuclear weapon into LEO. The resulting EMP from the detonation would cause indiscrimi-

CHINA IS LIKELY ALREADY DEVELOPING LASER WEAPONS AS PART OF ITS COUNTERSPACE STRATEGY.

nate damage to satellites, creating a high level of radiation in LEO that could last for years.[92] While China has the technology necessary to field a nuclear-armed ASAT weapon, it appears to be focusing its efforts in other areas.

Electronic

In the late-1990s, China acquired foreign ground-based satellite jamming equipment from Ukraine and has continued to develop the technology independently in the ensuing decades.[94] Currently, China has the ability to jam common satellite communication bands and GPS signals, and it has made the development and deployment of satellite jamming systems a high priority.[95] China is further developing jamming systems that will be able to target a large range of frequencies of commercial SATCOM as well as U.S. military protected communication bands.[96]

"The PLA considers EW [electronic warfare] capabilities key assets for modern warfare and its doctrine emphasizes using EW weapons to suppress or deceive enemy equipment."

DEFENSE INTELLIGENCE AGENCY, CHALLENGES TO SECURITY IN SPACE[93]

Chinese technical writings have been outspoken on how electronic warfare may increase its advantage in a conflict with the United States. A paper from the China Electronic Technology Group Corporation proposed solutions for "overcoming the high-power requirements for jamming U.S. millimeter wave (MMW) satellite communications by using space-based jammers hosted on small satellites, in a 'David versus Goliath' attack." The authors further identified U.S. satellites that would be particularly susceptible to such an attack, like "the Advanced Extremely High Frequency (AEHF), Wideband Global SATCOM (WGS), and Global Broadcast Service (GBS) satellite constellations."[97] Another Chinese technical paper provides further insight into how China plans to jam GPS signals used by U.S. drones, such as the RQ-4 Global Hawk, over the Spratly Islands and South China Sea.[98]

After the early 2020 U.S. drone strike on the Iranian general Qasem Soleimani, a Chinese military analyst commented that China would be able to detect an incoming strike through its early warning radars and anti-access/area denial (A2/AD) systems. He went on to say that China would be able to shoot down the drone with its air defenses and, as an added layer of defense, could conduct a "soft kill" by jamming the drone's communications and GPS.[99]

China has deployed military-grade truck-mounted jamming equipment in its buildup of military installations in the man-made islands in the South China Sea. As of April 2018, U.S. officials confirmed that there are two islands in the Spratly Island chain that have been equipped with jamming systems for targeting communications and radar. This assessment was supported by satellite imagery that shows a suspected jamming system on Mischief Reef in the Spratly Islands. While China has been building military installations across the island chain since 2014, this is the first visual evidence of jamming equipment there.[100] Shortly after the identification of the jammers, Vietnam condemned China's continued militarization and weaponization of the South China Sea and the Spratly Islands, also stating that the jamming equipment violates international law.[101]

In 2018, the SSF even carried out advanced military exercises simulating a complex electronic warfare environment with the "SSF base pitted against five PLA Army, Air Force, and Rocket Force units."[102]

China also reportedly developed a J-16D aircraft equipped with jamming systems. This aircraft, which suspiciously looks like the U.S. Navy's EA-18G Growler electronic attack fighter, is equipped with "several new antennas and conformal electronic-warfare arrays along the fuselage." According to the *National Interest*, the "D" in J-16D comes from *"diànzǐ,"* the Chinese word for electronic.[103]

Spoofing in the Port of Shanghai

INCIDENTS WERE REPORTED SPORADICALLY THROUGHOUT 2018 and 2019 of the GPS signals for Automatic Identification System (AIS) transponders being inaccurate in the main port of Shanghai. AIS signals broadcast the location, speed, and direction of a ship, as required by international maritime law.[104] Documented by a U.S. container ship, the *Manukai,* spoofing activities caused nearby ships' signals to be misrepresented in ways that could have caused a serious disaster. For example, a nearby docked ship's signal was reported as traveling down the channel toward the *Manukai* at significant speed. However, the captain of the *Manukai* could visually identify the ship in question as clearly docked and unmoving in a nearby slot at port. The incident did not stop there throughout the day, while the *Manukai* was securely docked at port, its AIS signals were reporting the ship being over three miles away from its actual location. The *Manukai* reported the incident to the U.S. Coast Guard which determined that there were "no known anomalies that might affect GPS signal integrity at the time and vicinity of the reported problem."[105]

Stunning for researchers is the peculiar circular shape of the plot of the spoofed ships and other GPS receivers in the area. Dubbed "crop circles" by confused researchers, this shape is unusual for GPS spoofing. According to Todd Humphries, a leading authority

on GPS jamming and spoofing, of the Radionavigation Laboratory at the University of Texas, Austin, declared "To be able to spoof multiple ships simultaneously into a circle is extraordinary technology." It is extraordinary because a single attack appears to have been able to spoof several vessels simultaneously, each to a different inaccurate location.[106] Furthermore, the D.C.-based research organization C4ADS also confirmed that civilian GPS was affected.

While the source of the spoofing remains unconfirmed, one expert traced the epicenter of the crop circle pattern to a non-operational smokestack near the port and speculates that it could be the origin of these GPS attacks.[107] GPS jamming and spoofing requires a direct line of sight to the target receiver. Therefore, to maximize impact and distance, many jamming devices are mounted on something with great height. For example, most military-grade truck-mounted jammers are mounted on a tall radio tower that maximizes the range of the effects.

Who is responsible? Again, this remains unclear. Early sources speculated that the attacks are actually GPS hacking caused by a non-state actor: sand smugglers.[108] However, the technology appears to be quite advanced, which researchers believe indicates that the Chinese government may be behind these attacks.

Another analyst, Bjorn Bergman, was intrigued by the reports and found similar crop circle phenomena in at least 20 other locations along the Chinese coast. Bergman assessed that 16 of these identified sites were oil terminals. A few of the other sites were Chinese government installations. Bergman assed that the oil terminals suggest that this could be an effort by the Chinese government to support Iran through importing Iranian crude oil in violation of sanctions.[109]

Due to the proximity to oil terminals, Bergman similarly assesses that the spoofing signals are being broadcast by the Chinese government.[110] Similarly, Humphries believes it is unlikely that a non-state actor could have developed this highly advanced technology.[111]

Figure 4 (above): GPS Crop Circles Near Dalian China. Research organization Skytruth found that two GPS interference locations around an oil terminal were active and had a dramatic effect on scrambling vessel positions in the area on September 5, 2019. Some vessels were even shown to be far inland. "On the water many positions are appearing with very high speeds (over 25 knots, red) and it's not possible to distinguish true and false locations. However, some slow speed positions (green) are appearing at dock where they would be expected, so some AIS broadcasts appear to be unaffected."

SKYTRUTH / AIS DATA COURTESY OF GLOBAL FISHING WATCH / ORBCOMM / SPIRE.

Figure 5 (below): Map of Reported AIS Outages Depicting the Crop Circle Patterns.

SKYTRUTH / AIS DATA COURTESY OF GLOBAL FISHING WATCH / ORBCOMM / SPIRE

"The PLA unit responsible for conducting signals intelligence has supported cyberespionage against U.S. and European satellite and aerospace industries since at least 2007."

DEFENSE INTELLIGENCE AGENCY, CHALLENGES TO SECURITY IN SPACE[112]

Cyber

Through the SSF, China has been integrating its advanced cyber capabilities with its counterspace and electronic warfare operations. The U.S. Defense Intelligence Agency assessed that: "The PLA could employ its cyberattack capabilities to establish information dominance in the early stages of a conflict to constrain an adversary's actions, or slow its mobilization and deployment by targeting network-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), logistics, and commercial activities."[113]

Chinese hacks against secure government networks to steal personal information and technical data are well known, but the country's efforts to attack and infiltrate space systems has received relatively less attention.[114] Chinese writings and research efforts indicate that in a conflict it would attempt to conduct cyberattacks against U.S. satellites and ground stations.[115] Specifically, "PLA military writings detail the effectiveness of information operations and cyberwarfare in modern conflicts, and advocate targeting an adversary's Command and Control and logistics networks to affect the adversary's ability to operate during the early stages of conflict."[116]

China has already been implicated or suspected in several cyberattacks against U.S. satellites.[117] In October 2007 and again in July 2008, cyberattacks believed to originate in China targeted a remote sensing satellite operated by the U.S. Geological Survey called *Landsat-7*. These attacks are believed to have occurred through a ground station in Norway.[118] Each attack caused 12 or more minutes of interference with ground station communications, but the attackers did not gain control of the satellite. In June and October of 2008, hackers also believed to be from China attacked the National Aeronautics and Space Administration's (NASA) Terra Earth observation satellite. In these attacks, the hackers "achieved all steps required to command the satellite but did not issue commands."[119]

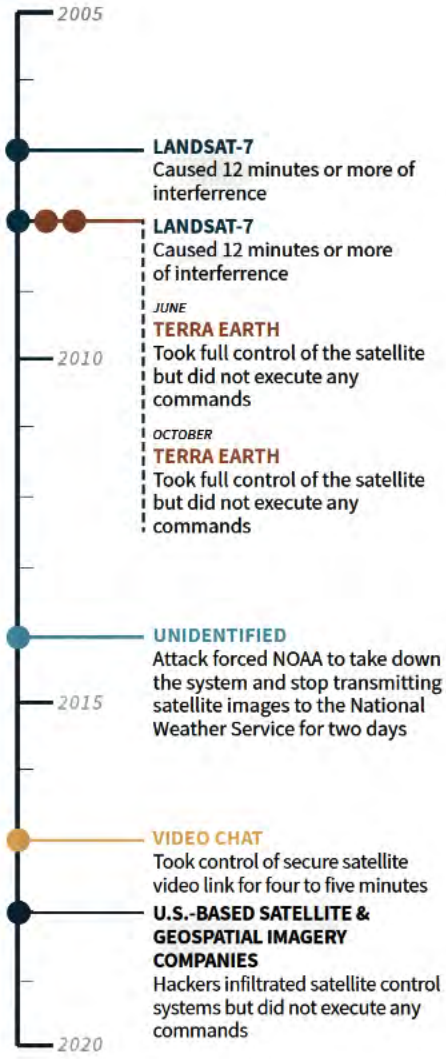

Figure 6: Timeline of Suspected Chinese Cyber Interference with Space Systems.

VARIOUS SOURCES COMPILED BY THE AEROSPACE SECURITY PROJECT

A 2019 NASA Inspector General report references several Chinese cyber intrusions into NASA, including a 2009 Chinese cyberattack on the Joint Propulsion Laboratory (JPL) which resulted in 22 gigabytes of data being transferred to a Chinese IP address. Another transfer of data to Chinese IP addresses occured in 2011 when "intruders gained full access to 18 servers supporting key JPL missions, including the DSN [Deep Space Network] and Advanced Spaceborne Thermal Emission and Reflection Radiometer mission, and

sensitive user accounts." The Advanced Spaceborne Thermal Emission and Reflection Radiometer mission is a joint project between NASA and Japan's Ministry of Economy, Trade, and Industry.[120]

In September 2014, Chinese hackers attacked National Oceanographic and Atmospheric Administration's (NOAA) satellite information and weather systems. The attack forced NOAA to take down the system and stop transmitting satellite images to the National Weather Service for two days before the organization was able to seal off the vital data.[121] After the attack was made public almost two months later, U.S. Representative Frank Wolf (R-VA) announced that NOAA had informed him that China was responsible for the hack on its systems. Chinese officials denied these claims, asserting that cyberattacks are common in today's world.[122]

Anonymous sources in India leaked in October 2017 that a "high-profile government meeting last month involving video chat via satellite was compromised by Chinese hackers". The video was in Chinese control for four to five minutes before Indian cybersecurity teams were able to launch a counterattack and neutralize the breach. The sources also claimed that the attack was able to breach the nation's "most sophisticated and secret link." However, the sources note that the Indian response team was unable to conclusively identify if the attack came from the Chinese government or non-state cybercriminals.[123]

On June 19, 2018, several researchers at Symantec—a U.S. software company—reported that a "sophisticated hacking campaign launched from computers in China burrowed deeply into satellite operators, defense contractors and telecommunications companies." The two targeted companies were U.S.-based satellite companies, a DoD submarine contractor, and a U.S. geospatial imaging company.[124] The researchers could not determine exactly which systems had been accessed in the breach, but they did admit that "the hackers infected computers that controlled the satellites, so that they could have changed the positions of the orbiting devices and disrupted data traffic." While Symantec did not directly blame the Chinese government for the attack, the company made it clear that the well-coordinated attack originated from the Chinese mainland.[125]

Later in 2018, the United States charged two Chinese nationals for their involvement in a decade-long cyber theft program, sponsored by the Chinese government. The program targeted aerospace industry companies, as well as NASA's Goddard Center and JPL. However, specific details of attacks by this group remain classified.[126]

SUMMARY

Overall, there appears to be an interesting shift in Chinese counterspace developments in 2019. Through the open-source assessment above, it appears that China has paused, or at least slowed, development and testing of its kinetic physical counterspace capabilities. This could be because its kinetic ASAT capabilities are well developed or because kinetic physical counterspace weapons are overt weapons that would likely draw a strong international condemnation if ever used. However, beginning in late December 2019 and through early January 2020, there is evidence that China's inspector satellite, *SJ-17*, was moving around in GEO, possibly signaling a return to operations after a hiatus of nearly a year.[127]

China is greatly increasing its development, testing, and fielding of non-kinetic physical and electronic counterspace weapons. The operational deployment of lasers capable of dazzling or blinding U.S. satellites seems imminent, if it has not occurred already. Furthermore, China is growing bolder with its electronic jamming and spoofing capabilities and may be using these technologies to hide illegal activities on its own coast or in the South China Sea. In 2020, it is likely that satellite jamming and spoofing capabilities will continue to be deployed and used in areas of gray zone conflict, such as the South China Sea and perhaps even to deter protests in Hong Kong.

China's cyberattacks against space systems have either not been publicly discussed or did not occur in 2019. However, this does not mean China is incapable of using cyber means to attack vulnerable space systems or has abandoned this line of effort.

Number of Successful Orbital Launches in 2019[128]

25

RUSSIA

"[Russian] leadership must be restored [in the space domain]. This is not just a question of prestige, but of national security."

DMITRY MEDVEDEV, FORMER RUSSIAN PRIME MINISTER[129]

WITH THE DISSOLUTION OF THE SOVIET UNION IN 1991, Russia inherited both the majority of the former state's vast space infrastructure and its place among the global space powers.[130] Since then, Russia has maintained a leading role in the global space community by operating the third-largest number of satellites on orbit, serving as a critical partner in international human spaceflight, and managing several of the world's busiest spaceports—all while facing an inconsistent federal budgetary environment and claims of widespread internal corruption.[131] By some metrics, Russia's space activity pales in comparison to the Soviet Union, which launched more payloads to orbit than all other countries combined before its collapse.[132] Other measurements, however, such as launch vehicle reliability and human spaceflight achievements, describe a formidable space actor with remarkable resilience in a rapidly changing space domain.

As the only ISS partner agency with a human-rated launch vehicle, Russia is responsible for ferrying all astronauts to and from the space station using its Soyuz rocket.[133] Since the U.S. Space Shuttle's final flight in 2011, Russia has launched 53 foreign astronauts to the ISS, including 34 Americans.[134] At over $80 million per seat, carrying passengers to orbit makes up 17 percent of the Russian space agency's annual budget, according to leaked budget documents from 2018.[135] For decades, NASA has had plans to develop a U.S. launch vehicle capable of transporting its astronauts to the ISS, lowering its dependence on the Russian Soyuz launch vehicle. With the first crewed flight test of the SpaceX Dragon capsule expected later this year as part of the U.S. Commercial Crew Program, the Russian space agency may soon find itself with many fewer human spaceflight customers compared to the past decade.[136]

RUSSIA

Despite the geopolitical tensions on Earth, Russia has pursued robust international partnerships in the space domain in addition to its commitments as part of the ISS agreement. For example, the Russian space agency has entered into discussions with the China National Space Administration to pursue cooperative lunar exploration missions beginning in 2020.[137] Since 2011, Russia has used the low-latitude Guiana Space Centre operated by the European Space Agency to launch Soyuz rockets, making it the only country in the world to launch a native orbital launch vehicle from a spaceport operated by another space agency.[138] Russia has also indicated its interest in continuing its partnership with the United States after the ISS retires.[139]

While largely successful, the Russian space industry has also been plagued with serious corruption scandals. In 2018, Russia's principal federal investigation authority discovered that fraud cases within the country's space and defense industry reached $1 billion.[140] Roscosmos, the Russian space agency, has been particularly wrought with corruption. Last year, a high-level agency official—who was likely linked to an internal embezzlement scheme—fled the country to Europe while he was under investigation.[141] Also in 2019, 58 people received jail sentences after $172 million was stolen from the Vostochny spaceport in the Russian Far East.[142] Only a fraction of the monies lost had been recovered as of November 2019. When asked about the culture of corruption at Roscosmos, the director of the Russian Investigative Committee said "there is no end in sight."[143]

In light of these issues, Roscosmos has announced extravagant spaceflight plans for the upcoming decade. In a presentation to students at Moscow University in May 2019, the agency's director announced the country's plans to invest in a new crewed space vehicle with flights to the ISS by 2023, develop a new heavy-lift launch vehicle, and even land cosmonauts on the Moon by 2030.[144] The scale of these new missions would almost certainly require the country to increase its budget for space activities, likely putting the space agency at odds with other federal spending priorities.[145]

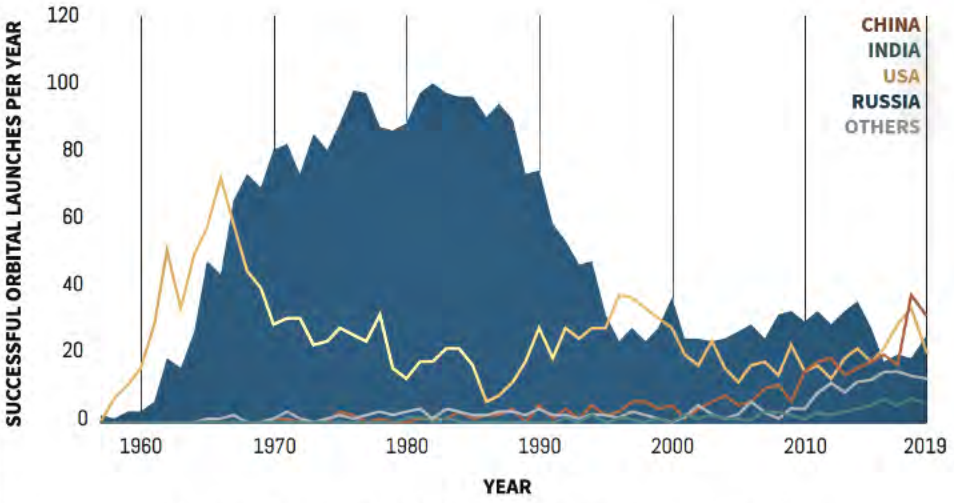

Figure 7: Russian Orbital Space Launches (1957-2019).

SPACETRACK.ORG / CSIS AEROSPACE SECURITY[148]

SPACE ORGANIZATION AND DOCTRINE

Most state-sponsored space activities in Russia are linked to one of two government organizations: Roscosmos, the country's civilian space body, and the Russian Aerospace Forces, the branch of the Russian armed services tasked with military operations in the space domain. Roscosmos, known as the Russian Federal Space Agency until 2015, inherited significant space infrastructure from its predecessor, the Soviet space program.[146] Tasked with the pursuit of international cooperation with space partners around the world, Roscosmos is one of five principal partners that support the ISS, along with civilian space agencies in the United States, Japan, Canada, and Europe.[147]

When the Russian Ministry of Defense was created in 1992, Russia established the world's first space force.[149] Now known as the Russian Space Forces subbranch—a part of the broader Russian Aerospace Forces—the Russian Space Force is responsible for launching military satellites, maintaining space-based assets, monitoring space objects, and identifying potential attacks against the Russian homeland from space.[150]

Russia considers the "intention to place weapons in outer space" a main external military danger and describes establishing "an international treaty on [the] prevention of placement of any types of weapons in outer space" as a principal task for the Russian state in its military doctrine.[151] Although Russia and China co-submitted the "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects" to the Conference on Disarmament in 2008, the United States dismissed the proposal as a "diplomatic ploy," and refused to support it.[152] In 2014, Russia and China reintroduced the treaty, prompting a similarly chilly reaction from the United States. In response to the Indian ASAT

test in March 2019, the Russian Ministry of Defense acknowledged India's otherwise strong dedication to preventing an arms race in space while simultaneously blaming the United States for creating an environment in which developing space actors are compelled to test anti-satellite weapons on orbit—a clear jab at U.S. opposition to Russia and China's failed treaties.[153]

Although Russia's military doctrine has not been publicly updated since December 2014, some analysts expect a new version may be released later this year.[154] Since the last military doctrine was released, Dmitry Rogozin—the Roscosmos director general and former deputy prime minister for defense—has stated that Russia does not use satellites to damage other space objects.[155] More recently, Russian military leaders have suggested that the Trump administration's support of the U.S. Space Force warrants new "reciprocal and asymmetrical measures" from Russia in the space domain.[156] In a December 2019 address, Russian President Vladimir Putin stated that the creation of a U.S. Space Force requires Russia to further invest in its own military space industry.[157]

COUNTERSPACE WEAPONS

Kinetic Physical

Evidence suggests that Russia has invested in a sweeping range of kinetic physical counterspace capabilities over the past decade, including ground- and air-launched direct-ascent ASAT missiles capable of targeting satellites in LEO and co-orbital ASAT weapons that could operate in any orbital regime. Russia's kinetic physical counterspace activities often closely resemble previously operational Soviet-era ASAT programs, suggesting that the country has benefited from decades of ASAT weapons research conducted by the Soviet Ministry of Defense.

On October 20, 1968, the Soviet Union became the second country in the world to successfully demonstrate a counterspace weapon when it destroyed a domestic satellite in LEO using a co-orbital ASAT. Called *Istrebitel Sputnikov (IS)*, meaning "satellite destroyer" in Russian, the first Soviet co-orbital ASAT was tested 20 times between 1963 to 1982, destroying several targets launched as part of the program.[158] A follow-on version of the *IS* system, known as IS-MU, was operational from 1991 to 1993.[159]

Prior to the fall of the Soviet Union, the country began developing a much more capable co-orbital ASAT known as the *Naryad*. Reportedly designed to reach altitudes as high as 40,000 km and contain multiple warheads in a single launch, the *Naryad* would likely have posed a serious threat to satellites in GEO.[160] The system saw limited testing—with just one launch in 1994—and no confirmed intercepts.[161]

Unlike the Soviet Union, Russia's kinetic physical counterspace arsenal includes ground-launched direct-ascent ASAT missiles. In December 2018, Russia conducted its seventh test of the PL-19/*Nudol* direct-ascent ASAT system.[162] The PL-19/*Nudol* completed its first successful flight test in November 2015, after two unsuccessful attempts.[163] Unclassified U.S. reports suggest that both this launch, and a previous test in March 2018, used a mobile transporter erector-launcher (TEL) within the Plesetsk Cosmodrome complex instead of a static launch pad.[164] Although at least six of the seven launches are verified to have originated from Plesetsk, a mobile launch system would theoretically allow the ASAT to be launched outside of the Cosmodrome facility, ensuring greater flexibility to target LEO satellites in inclinations above 40 degrees as they transit over Russian territory.[165]

Although not specifically designed as direct-ascent ASAT weapons, Russian mobile-launched S-400 surface-to-air missiles—capable of reaching a maximum altitude of 200 km—could potentially reach a satellite in LEO. The follow-on surface-to-air missile system, the S-500, is expected to reach altitudes up to 300 km if launched directly upward.[166] Oleg Ostapenko, Russia's former deputy minister of defense, once stated that the S-500 will be able to intercept "low-orbital

satellites and space weapons."[167] First tested in 2018, the new missile's production timeline has since slipped, and "there has been no indication of when an actual S-500 will be made available."[168] Like the PL-19/*Nudol* system, using the S-400 or eventually the S-500 as a direct-ascent ASAT would require a high-precision targeting capability that has yet to be demonstrated via a destructive test.[169]

A modified Russian MiG-31 fighter jet was photographed in September 2018 carrying an unidentified missile that some reports suggest could be a "mock-up" of an air-launched ASAT weapon.[170] Although this development follows a 2013 statement from the Russian Duma expressing the Russian government's intent to build an air-to-space system designed to "intercept absolutely everything that flies from space," the system depicted in the September 2018 photo would almost certainly be limited to targeting objects in LEO, due to its size.[171] In 2017, a Russian Aerospace Forces squadron commander confirmed that an ASAT missile had been designed for use with the MiG-31BM aircraft—the same variant spotted with the mysterious missile.[172] Citing several sources familiar with a U.S. report on the new weapons system, CNBC reported that the missile may become operational as soon as 2022.[173]

Russia has not publicly announced the development of a new co-orbital ASAT program since the fall of the Soviet Union. In the past few years, however, the Russian Aerospace Forces has launched a series of small "inspector" satellites in LEO that have demonstrated some of the technologies required to operate such a system. In 2017 and 2018, three small Russian satellites—Cosmos 2519, 2521, and 2523—engaged in RPO in LEO, prompting a statement of concern from the U.S. State Department.[174] Although a June 2017 Russian Soyuz launch appeared to place just one satellite in LEO—Cosmos 2519—a second satellite was detected two months later, likely deployed from the first as a subsatellite.[175] The Russian Ministry of Defense made a statement saying that the second satellite was designed to "inspect the state of a Russian satellite."[176] In October 2017, a third satellite was deployed from either Cosmos 2519 or its subsatellite, resulting in three independent satellites in orbit. Over the course of several months, the satellites engaged in a series of maneuvers and RPO exercises, including slow flybys, close approaches, and rendezvous. In February 2020, Chief of Space Operations of the U.S. Space Force General John Raymond appeared to refer to one of these three satellites when he said that Russian inspector satellites have "exhibited characteristics of a weapon."[177]

Analysis published in *Jane's Intelligence Review* used Russian procurement documentation and contractor reports to connect Cosmos 2519, 2521, and 2523 with the program name *Nivelir*.[178] Contracts signed in 2016 between the *Nivelir* program and a Russian company known for developing radiation-absorbing materials suggest that future *Nivelir* satellites—such as Cosmos 2535, 2536, 2537, or 2538, all launched in July 2019—may be coated with a protective film to avoid being tracked by optical or infrared sensors from the ground or in space.[179]

MiG-31BM "Foxhound" Aircraft on September 14, 2018. Photographed at the Zhukovsky airfield outside of Moscow, the aircraft is carrying what has since been identified as a potential anti-satellite weapon.
SHIPSASH / JETPHOTOS.COM

Spying on a Spy Satellite

ON NOVEMBER 25, 2019, Russia launched a small satellite, Cosmos 2543, into what the Russian Ministry of Defense described as a "target orbit from which the state of domestic satellites can be monitored."[180] Two weeks later, the ministry announced that a subsatellite, Cosmos 2542, had been deployed from Cosmos 2543.[181]

Three days after its deployment, Cosmos 2542 performed an orbital maneuver to synchronize its orbit with USA 245, what is believed to be a U.S. National Reconnaissance Office (NRO) satellite. Amateur satellite observers who record and share satellite observations online noticed that USA 245 performed its own maneuver soon thereafter, possibly to steer clear of Cosmos 2542.[182] In January 2020, Cosmos 2542 maneuvered toward the American spy satellite again, this time coming as close as 50 km.[183] A day later, USA 245 made another maneuver, further distancing itself from the Russian inspector satellite.[184]

In an interview with *SpaceNews*, General John Raymond, the Commander of U.S. Space Command and Chief of Space Operations of the U.S. Space Force, confirmed the close approach, adding that he believed it was intentional.[185]

Russia's newest co-orbital system may be designed to target satellites in GEO.[186] Designated *Burevestnik*, this program will likely employ low-thrust but highly-efficient electric propulsion to maneuver lightweight satellites—possibly similar to those from the *Nivelir* program—around the GEO belt.[187] A report published in 2019 indicated that a new ground control center was being built for *Nivelir* and *Burevestnik* at the same site the Soviets used to control the *Istrebitel Sputnikov* missions in the 1960s.[188]

Although there is no evidence yet of lightweight Russian satellites maneuvering in the GEO belt, a larger satellite has been observed engaging in suspicious RPO activity in the regime. The satellite—known as *Olymp-K* or *Luch*—has attracted attention for shifting its position within the geosynchronous belt on a relatively frequent basis, occupying at least 19 different positions since its launch in September 2014.[189] *Luch* first attracted attention when it repositioned itself between two satellites operated by Intelsat, a U.S. satellite communications company.[190] Approaching satellites in GEO in this manner could allow for close inspection or potentially interception of their communication links.[191] In September 2015, *Luch* approached a third Intelsat satellite.[192] The international response escalated in September 2018, when French Minister of the Armed Forces Florence Parly accused Russia of committing "an act of espionage" after it approached a French-Italian military satellite "a bit too closely" in October 2017.

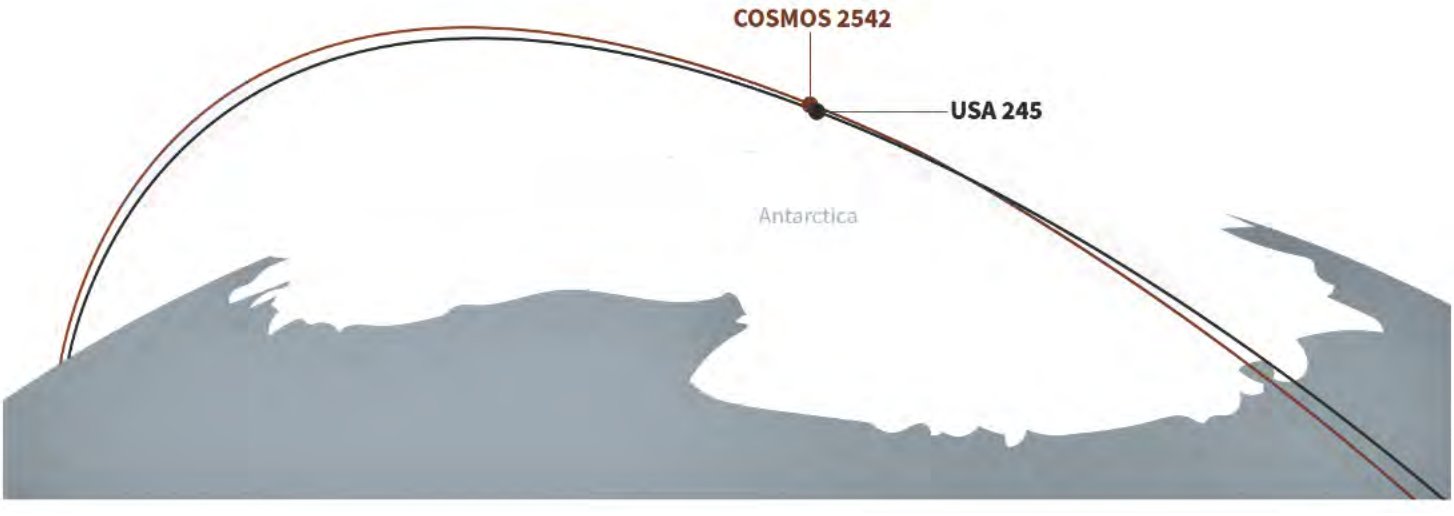

Figure 8: Orbital Trajectories for Cosmos 2542 and USA 245 on January 23, 2020. Since orbital parameters for classified satellites do not appear in the U.S. Space Command's public catalog of space objects, analysts use observations from amateur astronomers to calculate USA 245's orbital trajectory.

NICO JANSSEN / SATOBS.ORG

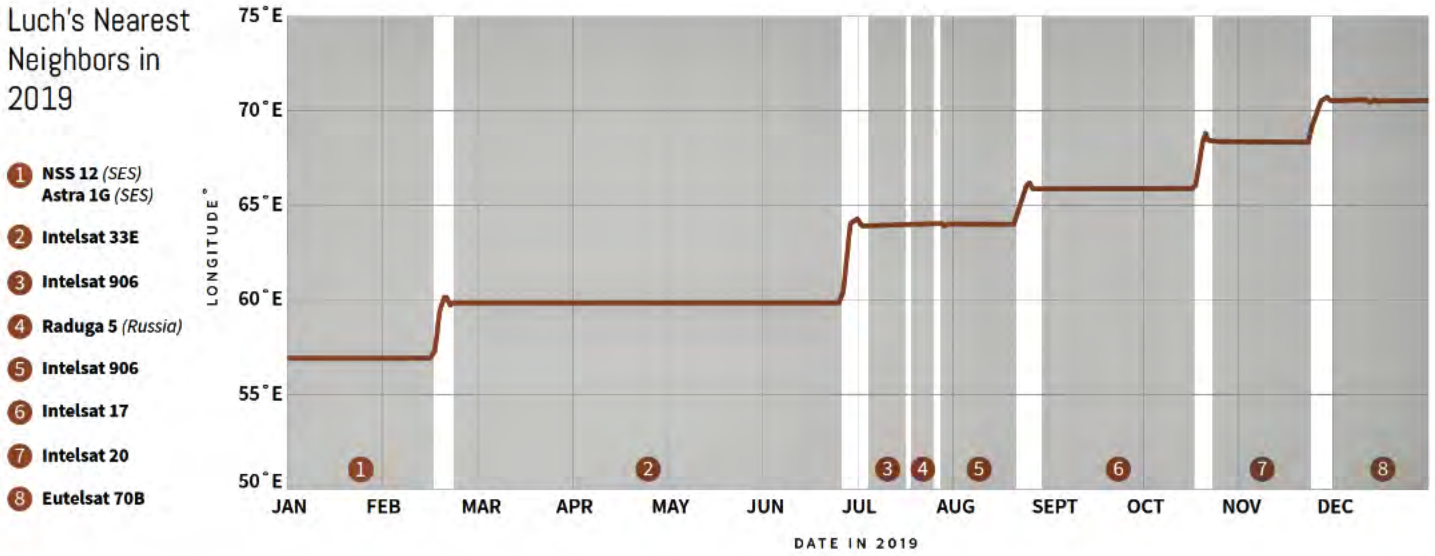

Figure 9: Luch Continues to Explore the GEO Belt. The Russian satellite has stopped at 19 different positions in the geostationary belt since its launch in 2014, including those depicted here in 2019. Learn more about Luch's behavior, including a list of the satellite's nearest neighbors at aerospace.csis.org/luch.

SPACE-TRACK.ORG / CSIS AEROSPACE SECURITY

Analysis of *Luch*'s on-orbit behavior since its launch in 2014 suggests that the satellite has approached 11 unique Intelsat satellites, four Eutelsat satellites, two SES satellites, and at least nine other satellites operated by Russia, Turkey, Pakistan, the United Kingdom, and the European Space Agency.[193] Although *Luch* appears to be maneuvering around the GEO belt in a systematic, deliberate manner, no public reports suggest it has damaged any of the neighboring satellites along the way.

Non-Kinetic Physical

Evidence suggests that Russia has both maintained its non-kinetic physical counterspace capabilities from the Soviet era—including detonating nuclear weapons at high altitudes, using nano-sized obscurants on orbit, and placing laser weapons on aircraft—and built upon them over the past 10 years.

In 1962, the Soviet Union detonated three nuclear warheads about 400 kilometers above the Earth's surface—near the altitude of the U.S. Starfish Prime test that same year—in a series of tests known as Operation K.[195] As suspected by the Soviet engineers who planned the tests, Operation K demonstrated the devastating effects of an EMP weapon in LEO. Though nuclear warheads were tested as part of the early *Istrebitel Sputnikov* tests, the program's successful intercepts used conventional warheads instead, which lowered the risk of inadvertently damaging Soviet satellites on orbit during testing.[196] Thirty years later, Vladimir Lukin, a senior Russian legislator, reminded the international community of Russia's retained EMP capabilities when he threatened a delegation of U.S. congressmen during an official visit in May 1999, saying:

> *Hypothetically, if Russia really wanted to hurt the United States . . . [it] could fire a submarine launched ballistic missile and detonate a single nuclear warhead at high-altitude over the United States. The resulting electromagnetic pulse would massively disrupt U.S. communications and computer systems, shutting down everything. No internet. Nothing.*[197]

"We have achieved significant progress in laser weapons."

VLADIMIR PUTIN, RUSSIAN PRESIDENT [194]

Academic articles, government contracts, and patent documentation suggest that Russia is sponsoring scientific research into on-orbit aerosol obscurants—nanoparticles that can block radiofrequency and optical signals to and from a satellite—which could be used to hide Russian satellites from space situational awareness sensors on the ground or as part of an offensive co-orbital attack.[198] According to analysis published by the website Space Review, Russia's Scientific Research Institute of Applied Chemistry (NIIPKh), known for its previous work in aerosol particle development, was awarded a contract from the previously-discussed *Burevestnik* program in 2015. Although there is no evidence that particle obscurants have been tested on orbit, an article written by NIIPKh affiliates in 2016 suggested that the technology could be installed on satellites, where it could be used to defend assets from kinetic physical attacks but also for "disabling" satellites from a close distance.[199] If deployed from a nearby satellite, particle obscurants could be used to temporarily degrade a target satellite by obstructing optical sensors or interfering with radio communications to and from its ground stations.

Leaked photos, statements from Russian defense contractors, and Russian news reports suggest that a Soviet-era laser weapon from 1965 has been revived to target satellites in LEO.[200] In 2011, photos of a modified *Ilyushin Il-76MD* cargo plane, known as the *Beriev A-60*, featuring what appears to be an upward-facing laser on the fuselage and a targeting system built into its nose cone, were uploaded to an online forum for Russian plane enthusiasts. The system, known as *Sokol Eshelon,* was likely tested two years earlier to illuminate a Japanese satellite on orbit at an altitude of 1,500 km.[201] In 2017, the general director of Almaz-Antey, a weapons manufacturer with ties to the program, told a Russian news outlet that his company had been ordered to develop a system capable of "direct functional destruction of those elements deployed in orbit."[202] A year later, however, Interfax reported that Almaz-Antey had finished work on a new air-based laser ASAT system that would most likely rely on a "fundamentally new aircraft [that is] not based on the Il-76MD."[203] Regardless of the aircraft on which the laser weapon is mounted, such a weapon could be capable of damaging its targets' optical sensors and solar arrays from anywhere in Russia's vast airspace.

In a presidential address in March 2018, Russian President Vladimir Putin announced the development of a new directed-energy weapon.[204] Russian news outlets later reported that the ground-based laser weapon, known as *Peresvet*, was first delivered to Russian troops in July 2017 and had been placed on "experimental combat duty" in December 2018.[205] A video released by the Russian Ministry of Defense shows the weapon mounted on a trailer, suggesting some degree of mobility.[206] Russian officials told reporters that the system is distributed over two platforms, with the second responsible for the laser's power source. Yury Borisov—former Russian deputy minister of defense, now the country's deputy prime minister—commented that *Peresvet* would be made more compact over the next two to three years.[207] President Putin recently announced that the weapon would be placed "on standby alert" in December 2019.[208] Although the most critical details about *Peresvet* remain unknown.[209]

Electronic

The Russian government has been accused of widespread GPS jamming and spoofing since 2014, affecting civilian and military vessels near Russian territory, commercial and civilian aircraft in the Arctic Circle, and handheld consumer devices in downtown Moscow and St. Petersburg.[211] Despite overwhelming evidence that Russia has employed the use of mobile, ground-based electronic counterspace weapons on a regular basis both within its borders and abroad, the Russian state has repeatedly denied any wrongdoing.[212]

Since the beginning of the 2014 Crimean conflict, Russia has used a variety of jamming and radio-monitoring platforms—

"GNSS [Global Navigation Satellite System] spoofing activities in the Russian Federation, its occupied territories, and its overseas military facilities are larger in scope, more geographically diverse, and started earlier than any public reporting has suggested to date."

CENTER FOR ADVANCED DEFENSE STUDIES[210]

The Trailer-Mounted *Peresvet* Laser Weapon System. Some observers suspect that the laser's power levels will allow it to target satellites in LEO.

RUSSIAN DEFENSE MINISTRY

including the truck-mounted R-330Zh jammer and the R-381T2 radio monitoring system—to deny Ukrainian forces access to consistent GPS and satellite communication services.[213]

Similarly, Russia reportedly deployed a *Krasukha-4* truck-mounted jamming system in Syria, another conflict region, and supplied the Syrian army with R-330P radio jammers.[214] Using sensor data from the International Space Station, analysts at the Center for Advanced Defense Studies (C4ADS) and the University of Texas at Austin identified "potential military-grade EW systems" likely designed for "airspace denial purposes" at Khmeimim airbase, a Russian-operated air base in western Syria.[215]

Russia's use of electronic counterspace weapons is not restricted to conflict zones. Starting in late 2017, civilian and commercial aircraft operators in the northernmost region of Norway—Finnmark County, which borders Russia's Murmansk Oblast—began reporting recurring GPS signal outages during flight.[220] Analysis of notice to airmen (NOTAM) alerts distributed from September 2017 to January 2019 shows a correlation between GPS signal outages and military exercises in the region, including a Russian-Belarusian joint exercise in Russia in 2017, a NATO exercise in Norway, Sweden, and Finland in 2018, and a nearby British exercise in 2019. After Norway announced that Russia was responsible for the regional jamming incidents, the Norwegian Communications Authority made plans to establish a satellite signal measurement station to better understand the GPS jamming environment in the region.[221]

In 2017, over 20 ships operating in the Black Sea reported gross GPS position errors as they sailed near the Russian coast.[222] The incidents were first reported by the U.S. Maritime Administration. A C4ADS report from March 2019 identified hundreds more "denial-of-service" occurrences in the region from both before and after the original report where onboard GPS devices were calculating false coordinates for the vessels.[223] In many cases, GPS devices calculated ships' positions as being at a nearby Russian airport, and not in the Black Sea. The report—a collaborative study between C4ADS, the University of Texas at Austin, and Palantir Foundry—also suggested a specific location for at least one of the spoofing devices responsible: "a multi-million dollar 'palace,' formerly owned by family members of senior Federal Protective Service officers and previously reported to be built for President Putin."[224] The FSO is the Russian counterpart of the Secret Service in the United States, a federal agency responsible for senior government leaders' personal security.

The C4ADS report suggests that the FSO's relationship with Russia's use of electronic counterspace weapons does not stop at the seaside palace. The report identified 12 occurrences in which evidence of one-off PNT spoofing events corresponded with the movements of Russian President Vladimir Putin, his senior advisers, or FSO officers, suggesting that "some devices used to conduct this activity are mobile and can be temporarily deployed at a location to create local areas of effect."[225]

A $4,000 Taxi to the Kremlin

IN JUNE 2016, visitors to downtown Moscow began noticing a problem with their mobile devices' mapping services.[216] When driving or walking near the Kremlin, at the center of the city, users reported being directed to follow implausibly inefficient routes. In some cases, mapping software suggested a detour of just a few blocks. In others, mobile device users were directed as far away as the Vnukovo Airport, almost 50 kilometers southwest of the Kremlin.[217] Visitors were particularly affected when using ride-sharing services, complaining on Twitter about $3,000 to $4,000 fare estimates due to the mapping errors.[218]

These map users were likely receiving false positioning signals, leading them to specific, incorrect locations away from the Kremlin. Residents of St. Petersburg began reporting similar issues during a visit from President Vladimir Putin in December 2016.[219]

In two of those cases, the Russian president was visiting the newly-constructed Crimean Bridge, which physically connects Crimea with the Russian mainland. On May 15, 2018, the second of those two visits, President Putin celebrated the project's completion by driving across the bridge in a motorcade of construction vehicles. Based on the locations of the ships experiencing GPS spoofing at the time—which typically must be within the line of sight of the spoofing device feeding them false coordinates—it is possible that the spoofing device was contained in one of the vehicles in Putin's motorcade.

Several months after Putin's visit, the Crimean Bridge was the site of a military conflict in which Russia was accused of using electronic weapons. In November 2018, the Russian Coast Guard opened fire on three Ukrainian Navy ships as they attempted to pass underneath the Crimean Bridge from the Black Sea into the Sea of Azov, in what became known as the Kerch Strait incident. A month after the incident, which injured six sailors according to Ukraine, Ukrainian Navy Commander Ihor Voronchenko accused Russia of spoofing GPS signals and jamming access to the Iridium satellite communications network.[226]

Figure 10: Russian President Vladimir Putin Visiting the Newly Constructed Crimean Bridge Connecting Crimea to Mainland Russia on May 15, 2018. Denial-of-service reports from vessels near the bridge at the time of the visit suggest that a spoofing device may have been contained in one of the orange construction trucks that made up the president's motorcade.

ALEXANDER NEMENOV / AFP / GETTY IMAGES

In 2016, Russia announced plans to install GPS jammers on the country's 250,000 cell phone towers.[227] The system, called Pole-21, is aimed at providing more widespread GPS jamming to protect Russian assets against cruise missiles, drones, and precision-guided munitions. In November 2019, the Russian military confirmed that the first units have been delivered.[228]

Russian electronic counterspace activities may not be limited to ground-based systems. Late last year, Russian news reports suggested that the Russian Aerospace Forces may upgrade its *Porubshchik* electronic warfare aircraft, which could be used to jam satellite signals across wider regions than a truck- or tower-mounted jamming device.[229] Although there is no evidence in the public domain that Russia employs space-based electronic counterspace weapons, analysis of Russian procure-

ment documentation from 2014 points to a new program called *Ekipazh* that may feature a nuclear-powered jamming device on orbit.[230] Early reports from the program's manufacturers suggest that test flights could begin as early as 2021.

Cyber

Foreign governments regularly accuse Russia of widespread international cyberwarfare.[231] In the space domain, a group of hackers with links to the Russian Federal Security Service called *Turla* has been hijacking the internet services of older commercial satellites since 2007.[232] More recently, from 2017 to 2019, *Turla* infiltrated government agencies and private companies in more than 20 countries according to reports from the British National Cyber Security Centre and U.S. National Security Agency.[233] During the attacks, the group attempted to disguise themselves as an Iranian hacking organization by first gaining access to computer infrastructure previously associated with Iranian cyberattack operations. In April 2015, a French satellite TV network was pulled off the air in an attack linked to another Russian hacker group known as APT 28.[234] Later that year, APT 28 gained access to a British television station's computer network, but did not tamper with any of its broadcasted programming.[235]

Russian cyberattacks on state governments and international organizations extend well outside of the space domain, earning criticisms from Estonia, Ukraine, the United States, the United Kingdom, France, Germany, Kyrgyzstan, and the Netherlands.[236] In August 2019, NATO Secretary General Jens Stoltenberg specifically addressed Russia's nefarious activities in the cyber domain in an editorial about NATO's renewed cybersecurity efforts. No other state perpetrators were mentioned.[237] Russia's Ministry of Foreign Affairs has developed a consistent pattern of denying accusations of wrongdoing in the cyber domain, calling the negative attention "stage-managed propaganda campaign[s]" and "Western spy mania."[238]

SUMMARY

While the Soviet Union developed weapons in just two of the four counterspace categories—kinetic and non-kinetic physical weapons—Russia has invested in all four over the past 10 years. Evidence suggests that Russia is developing an air-launched direct-ascent ASAT missile, has already tested a ground-based direct-ascent ASAT, and is reinvigorating an array of co-orbital counterspace technologies more than 50 years after the Soviet Union became the first and only country to successfully destroy a target satellite using a co-orbital ASAT weapon. Russia has built off of the Soviet Union's arsenal of non-kinetic counterspace weapons by reviving a Soviet-era air-based laser weapon and unveiling a new ground-based trailer-mounted laser weapon. In just the past few years alone, Russia has become one of the world's greatest perpetrators of electronic counterspace warfare, jamming and spoofing PNT and communications satellite signals in conflict zones, nearby territories, and within its own borders. Although difficult to verify, Russia is also almost certainly capable of targeting satellites and associated ground stations through vulnerable computer networks. With new weapons added to the Russian counterspace arsenal each year since 2018, it is clear that the country has renewed its focus on developing and maintaining its ability to disrupt, degrade, or destroy adversaries' assets on orbit.[239]

Number of Successful Orbital Launches in 2019[240]

0

IRAN

"The United States will not allow Iran to use its space launch program as cover to advance its ballistic missile programs,"

MIKE POMPEO, U.S. SECRETARY OF STATE[241]

OFTEN CITED AS A THINLY VEILED COVER for its ballistic missile program, Iran's space capabilities are relatively minimal.[242] Iran's space and ballistic missile systems are likely based on Russian and North Korean programs. This analysis is supported by the weak aerospace industrial base in the country, suggesting that Iran is unlikely to have the technical and industrial capability to develop complex launch technology from scratch.[243] In 2009, Iran successfully launched its first domestically-manufactured satellite on a *Safir-1* rocket, making it the ninth country at the time to have launched an indigenous satellite.[244] The Iranian Space Agency (ISA) continues to claim to have sent various living creatures into space in the last decade, including a monkey two times in 2013.[245] The agency had previously aimed to put a human in space by 2025, but human spaceflight aspirations were put on hold in 2017 due to budget constraints, likely linked to U.S.-imposed sanctions. However, the ISA has continued to focus on improving its SLVs.[246]

Iran's main launch facility, the Imam Khomeini Spaceport, is located in a larger domestic space facility, the Imam Khomeini Space Center, in the Semnan Province east of Tehran. The site is also used as one of eight missile test and launch sites in the country.[247] Iran had four successful launches from 2009 to 2015 that put various operational satellites into orbit, none of which stayed in orbit longer than a few months.[248] In 2014, Iran reportedly signed an agreement with Russia for its assistance in the development and launch of Iranian satellites and possibly the training of future Iranian astronauts.[249]

IRAN

"Iran recognizes the strategic value of space and counterspace capabilities."

U.S. DEFENSE INTELLIGENCE AGENCY

The U.S. Intelligence Community has assessed that "Iran recognizes the strategic value of space and counterspace capabilities" and that continued work to develop space launch vehicles will shorten the timeline to create a successful ICBM.[250] Iran is an unusual case as countries have historically constructed space launch capabilities from military ballistic missile programs, not the other way around.[251] In addition to SLVs, Iran has also developed space capabilities with military applications such as a space monitoring center announced in June 2013 that uses radar, electro-optical, and radio tracking.[252] Iran continues to focus on space situational awareness monitoring, announcing in 2018 that experts built radars which can monitor satellites in LEO.[253]

Iran currently has two known launch vehicles, the *Safir-1* and *Safir-2*, the latter of which is commonly known as the *Simorgh*.[254] While the *Safir-1* has had successful orbital launches, the *Simorgh* has yet to complete a fully successful mission.[255] In July 2017, Iran announced a successful test launch of the *Simorgh*, although the success of the test has not been confirmed outside of state media.[256] For the Iraninan space program, 2019 proved to be a difficult year, with three failed orbital launches in January, February, and August, which used alternately the *Safir-1* and *Simorgh* launch vehicles.[257]

Failed Launch Attempt

ON AUGUST 25, 2019, the head of the Iran Space Agency was quoted in state media saying that the agency planned to launch three satellites into orbit by March of 2020. The goal of these three satellites would be to help aid civilians through improving navigational, agricultural, and environmental monitoring services.[258] Four days later, on August 29, satellite imagery from the Earth-imaging company Maxar Technologies showed a launch pad at the Imam Khomeini Space Center that appeared to be the aftermath of a failed launch attempt. Satellite imagery analysts were able to note that the pad had been recently painted, likely for the launch itself and to cover up previous damage from failed launches, with smoke billowing from the ground, indicative of a failed launch. An anonymous Iranian official admitted to Reuters that the incident was caused by technical issues but would not go into further detail.[259]

President Trump tweeted a high resolution image of the scarred launch pad, underscoring that the United States was not involved.[260] Although Iran has continued to claim its space program is peaceful, that has not always been the belief of the U.S. government, whose officials often remark that the space program may be a front for developing Iranian ballistic missiles.[261] Days after this third failed launch attempt of the calendar year, the Trump administration added the Iran Space Agency, the Iranian Astronautics Research Institute, and the Iran Space Research Center to the U.S. sanctions list.[262]

New satellite images surfaced in January 2020 which showed the launch pad being repaired, possibly in preparation for another launch attempt with a *Simorgh* launch vehicle.[263] This timing coincided with statements from the Iranian Minister of Information and Communications Technology, who announced that the program had six satellites ready to launch. He announced that two are communications satellites, named *Zafar-1* and *Zafar-2*, were reportedly ready for a launch in early February.[264] On February 9, 2020, the *Simorgh* rocket launched with a satellite on board, but the satellite did not reach high enough velocity to stay in orbit. A spokesman for the Iranian defense ministry's space program claimed that the Simorgh functioned properly, calling it a "remarkable" feat for the space program. The minister of Information and Communications Technology continued by saying the program is "UNSTOPPABLE! We have more Upcoming Great Iranian Satellites!"[265]

Figure 11: Satellite Image of Iranian Launch Attempt on August 25, 2019.

CSIS / MAXAR TECHNOLOGIES

SPACE ORGANIZATION AND DOCTRINE

Iran was one of the founding members of the UN Committee on the Peaceful Uses of Outer Space in 1958; however, the country is one of many that has signed but not ratified the Outer Space Treaty.[266] The Iranian Space Agency was established in 2004 ostensibly to coordinate peaceful applications of space activities and technology development for the country.[267] The agency is under the oversight of the Ministry of Information and Communications Technology, but takes direction from the Supreme Space Council, which is chaired by the president of Iran. The head of the space agency serves as the secretary of the Supreme Space Council, which is overseen by the president and focuses on making policy for peaceful space technologies, approving state and private space programs, and promoting domestic, private, and international cooperation in space issues.[268]

The Iranian Space Agency also runs the Iranian Space Research Center and reportedly has planned to establish a "space park," a space-themed center that focuses on education, culture, recreation, and amusement. The park would be run in partnership with the Sharif University of Technology (SUT), a well-known research university that supports the government in ballistic missile-related projects.[269] Little is publicly known about Iran's doctrine for space and counterspace operations, but evidence suggests that Iran believes the capability "to deny the United States the ability to use space in a regional conflict" is critical to its security.[270] Although the country often uses aggressive rhetoric when discussing ballistic missile activities, Iran consistently claims that its space program is peaceful.[271]

Budgets for the Iranian Space Agency have risen in the last decade. In 2010, the space agency had a reported budget of $1.5 million, which the minister of Communications and Information Technology enthusiastically reported saying "being in space is one of the key factors in the power of governments."[272] In 2017, the budget for the space agency was reported to be $4.6 million.[273] The space agency's budget is separate from Iran's military spending, which has increased by over 50 percent in the last five years, swelling to 7.5 percent of its total national budget for 2018–2019.[274] Though Iranian leadership takes steps to obscure the specifics of its military budget, priorities include improving domestic missile production capabilities. Because of limited domestic capability to produce reliable components, Iran continues to rely on imported components and materials for their missiles. Iran is not a major space power in terms of proven space capabilities, but it continues to invest in and develop significant counterspace capabilities.

COUNTERSPACE WEAPONS

Kinetic Physical

While currently available open-source information does not indicate that Iran is attempting to develop either direct-ascent or co-orbital ASAT weapons, Iran has some of the ballistic missile technology on which a future direct-ascent kinetic ASAT capability could be based. In addition to a diverse set of ballistic missile programs with varied ranges, Iran has substantial conventional forces, with an estimated 523,000 active personnel.[275] Iran's ballistic missile capabilities include the *Shahab-3*, which is believed to be derived from the North Korean *No Dong-1* missile.[276] The *Simorgh* SLV is similarly based on the North Korean *Taepo Dong-2*, including modeling *No Dong-1* engines.[277] Iran appears to have been able to reproduce these missiles in quantity, which led U.S. Secretary of State Mike Pompeo to publicly assert that "Iran has the largest ballistic missile force in the Middle East."[278]

Iran has demonstrated the rudimentary ability to launch and operate primitive satellites for short periods of time, and its space monitoring center gives it the ability to track objects and have better space situational awareness.[279] Having a reliable understanding of where objects are in space is required for targeting many capabilities. However, there are many other technological hurdles to tackle before Iran could field a direct-ascent kinetic ASAT weapon, such as precise onboard sensors that could guide a warhead into a target satellite.

Realistically, Iran could construct a crude direct-ascent ASAT capability by modifying an existing ballistic missile and launching it within the vicinity of a target satellite with an unguided warhead. It would not likely be able to hit a specific satellite but could create a debris hazard in the space environment that threatens the safety of numerous other satellites in similar orbits.

During a military parade in late 2019, Iran unveiled a new indigenous ballistic missile kit design, the Labbayk-1, which aims to modify unguided short-range *Zelzal* and *Fateh-110* ballistic missiles into guided weapons.[280] This new capability could lead to an increase in accuracy, as demonstrated in recent Iranian surface-to-air and air-to-air missile attacks in the Middle East.[281] This increased capability may pose a threat to space systems by being able to more reliably attack satellite ground stations throughout the Middle East and Europe.[282]

Non-Kinetic Physical

There are few reports of Iranian non-kinetic physical weapons, but the country may have acquired and used a laser dazzling or blinding counterspace system on a U.S. satellite. In 2011, an unnamed European intelligence source was quoted stating that Iran managed to "blind" a U.S. satellite by "aiming a laser burst quite accurately."[283] The technology necessary to do this, particularly the adaptive optics needed to steer and focus a laser as it passes through the Earth's atmosphere, is quite sophisticated, indicating that Iran may have obtained this technology from Russia or China. Its capabilities in this area remain highly uncertain based on the limited publicly available information.

If Iran were to continue pursuing a breakout nuclear capability, it is conceivable that it could launch a nuclear weapon into orbit as a nuclear ASAT capability. In the 1990s, Iran entered into agreements with both China and Russia to help jumpstart its nuclear program. China agreed to include the training of Iranian personnel and contribute various reactor technologies.[284] Iran has also entered into a bilateral nuclear cooperation agreement with Russia to provide nuclear experts, information, and aid in the completion of Iran's first nuclear power plant. [285]

Recently, the program has leaned most heavily on North Korean cooperation. In 2012, Iran and North Korea signed the Civilian Scientific and Technological Cooperation Agreement, which established joint facilities and a "transfer [of] technology"inmultiplefields.[286] Former Special Coordinator for the State Department's North Korea Group, David Asher, added "the last time North Korea signed an agreement like this it led to the largest act of nuclear proliferation in modern history."

Development of Iranian nuclear capability was temporarily slowed in 2015 by the Joint Comprehensive Plan of Action (JCPOA).[287] The United States pulled out of the JCPOA in 2018, and after a series of international events which increased tensions between the two nations, Iran also stated it would no longer adhere to the deal.[288] The remaining countries involved in the JCPOA, including Russia and China, hope to reimplement the agreement.[289] Despite pulling out of the JCPOA, President Trump reiterated as recently as January 2020 that Iran would "never be allowed to have a nuclear weapon."[290] However, the aim of Iran's nuclear program has historically been to develop a nuclear-armed ICBM to deter the United States, not a nuclear counterspace ASAT weapon.

Electronic

Jamming and spoofing are regular tools in Iran's weapons arsenal. In 2003, Voice of America (VOA) broadcasts into Iran began to experience interference with its transmissions over the Telestar-12 satellite. The uplink jamming of this commercial satellite originated from the area around Havana, Cuba. The U.S. State Department notified Cuba of the issue, and subsequently determined that the source of the jamming was from a compound belonging to the Iranian Embassy. Cuban authorities promptly shut down the facility and issued a note of protest to the Iranian government.[291] Similar attacks emanated from Bulgaria and Libya from 2005 to 2006. Though Iran's role went unconfirmed, "international pressure eventually brought this to a halt and satellite jamming against Persian-language programming now emanates exclusively from Iranian territory."[292]

> "We have been equipped with electronic warfare systems in order not to remain just a defending force, and rather become able to jam the enemy's communication systems,"
>
> BRIGADE GENERAL AHMADREZAPOURDASTAN[293]

Iran has also jammed several international and regional television broadcasts in the Middle East. In 2010, Iran jammed BBC and VOA satellite signals transmitting into Iran. At first, the jamming tar-

IRAN HAS DEMONSTRATED ITS CYBER CAPABILITIES BY ATTACKING U.S. INFRASTRUCTURE.

geted BBC and VOA broadcasts on the Hot Bird 6 commercial satellite, but when the broadcasts were moved to transmit through other commercial satellites, the jamming targeted those satellites as well.[294] In the same year, the head of the Islamic Republic of Iran Broadcasting publicly acknowledged that the Iranian government engaged in the jamming of foreign broadcast satellites.[295]

Al Jazeera faced targeted attacks in January 2012 after its coverage of the conflict in Syria. The origin of the attacks was traced to two locations in Iran.[296] Later that year, Iran was supported by the Syrian government in a coordinated jamming effort against approximately 25 international broadcasters, "including the BBC, France 24, Deutsche Welle and the Voice of America."[297] A similar report in July of 2019 stated Iran International, a London-based TV station, believed its signals were being blocked via uplink jamming originating from Iran.[298]

Iran has publicly claimed the ability to spoof GPS receivers. In 2011, Iran claimed to have forced a U.S. RQ-170 drone to land inside its borders by jamming its satellite communications links and spoofing the GPS receiver. An Iranian engineer was quoted at the time as saying that the drone landed "where we wanted it to, without having to crack the remote-control signals and communications."[299] Though a former Pentagon spokesperson claimed there was "no indication the drone was brought down by hostile activity of any kind," President Obama did acknowledge that Iran had possession of the drone.[300] If Iran's claims of electronic jamming are true, they represent a significant counterspace capability that could be used to thwart U.S. precision-guided weapons and aircraft in the future.

In 2019, there were similar reports of GPS spoofing of commercial U.S. ships in the Gulf of Oman. Several ships reported a loss of GPS signal and were captured in Iranian territorial waters. After 11 reported incidents, the U.S. Maritime Administration issued a warning to U.S. vessels to be aware of GPS interference in the area.[301] The advisory warned of Iranian GPS jammers operating on an island near the Strait of Hormuz with the goal of causing ships and aircraft to "inadvertently wander into Iranian waters or airspace in order to justify a seizure." The warning also mentioned instances of "spoofed" communications from ships claiming to be U.S. or other countries' warships.[302] Similar GPS interference was reported by British ships, prompting British media reports that intelligence services were concerned that Iran had used Russian GPS spoofing technology to guide the vessels into Iranian waters.[303] In 2019, numerous oil tankers from varying regions reported seizures in the Strait of Hormuz, followed by an Iranian shoot-down of a remotely piloted U.S. Navy aircraft over the international waters in the region.[304]

Also in 2019, the commander-in-chief of the Islamic Revolutionary Guard Corps (IRGC) announced the creation of a new mounted hardware unit called *Sepehr 110* to protect its systems from electronic warfare.[305] State media credits the system as being developed by IRGC experts and "invulnerable to hacks, eavesdropping, radio jamming, and electromagnetic disturbance" but there has been no external verification of the system.[306]

Later that year, the Research and Self-Sufficiency Jihad Organization of the Iranian army unveiled a portable jamming system attachable to vehicles and reportedly capable of detecting and disrupting drone flights.[307] These announced upgrades of counterdrone capabilities, including a system capable of participating in electronic warfare and radar evasion, have not been corroborated outside of state-sponsored media.[308]

Cyber

Iran began developing its cyber capabilities through independent hackers who gained notoriety in the early 2000s. The Iranian government often encourages its hackers through recruiting into its own cyber forces or supporting independent operations against its enemies, representing a somewhat unique approach.[309] Though initially modest, Iranian cyber capabilities have grown significantly in the last decade, becoming "notable players" in the cyber realm.[310] Iran has devel-

oped advanced offensive cyber capabilities that could potentially target U.S. space systems in the future. With three separate branches of the Iranian military contributing to cyber infrastructure, Iran claims over 100,000 cyberwar volunteers and recently established a Joint Chiefs of Staff Cyber Command to better organize its efforts.[311]

This increase in cyber activity has been mirrored in the country's budget; in 2017, the budget of the National Center for Cyberspace reportedly increased by 45 percent in one year, swelling to $1.2 million.[312] Iranian willingness to employ cyberattacks against targeted defense companies, media conglomerates, and adversaries also appears to be increasing.[313]

Iran has demonstrated its cyber capabilities by attacking U.S. infrastructure, though it has often targeted private companies as opposed to government systems. In 2012, Iran launched a distributed denial of service (DDOS) attack against U.S. banks and telecommunications companies, which resulted in monetary losses in the millions.[314] This particular incident prompted a public statement by then-Secretary of Defense Leon Panetta warning that the imminent threat of a cyberattack that could cause significant property damage or kill U.S. citizens would be sufficient justification for a pre-emptive military strike.[315] In 2019, the FBI was made aware of attempts, likely originating from Iran, to gain access to the systems of U.S. satellite technology companies.[316]

Various malware programs, including the destructive Shamoon virus with the ability to fully wipe computer systems, have been tied to Iranian state-sponsored hacking groups. The director of the U.S. Cybersecurity and Infrastructure Security Agency issued a warning describing a similar type of destruction, citing a "rise in malicious cyber activity" from Iranian actors.[317] As tensions rise worldwide with Iran, so do hacking attempts. In a 48-hour time period in January 2020, attacks from Iranian IP addresses were recorded at up to 500 million attempts per day globally.[318] Although there are few confirmed instances of Iran using cyberattacks against space systems, Iran's increasingly sophisticated cyber capabilities suggest that it could employ such attacks on space systems if needed.

SUMMARY

Iran is still far from developing direct-ascent ASAT weapons, even with its increased focus on launch vehicle development and continued development of ballistic missile capabilities. Similarly, with only four successful satellites that have reached orbit and a growing string of failed launches, Iran is unlikely to develop a co-orbital ASAT capability in the near future. To make significant progress on kinetic and non-kinetic counterspace systems, Iran would likely need to acquire technology and resources from a major counterspace actor, such as Russia or China. However, Iran has growing electronic and cyber counterspace capabilities and continues to demonstrate successful jamming and hacking attacks against foreign governments and civilian systems.

Part Two of this CSIS report and analysis will be published in the June issue of MilsatMagazine and includes the organization's information regarding North Korea, India and Others.

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