

SATCOM for Net-Centric Warfare

Milsat Magazine

October 2020 issue

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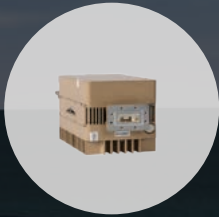
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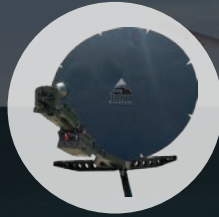
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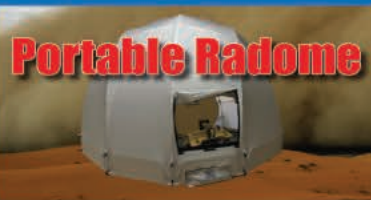
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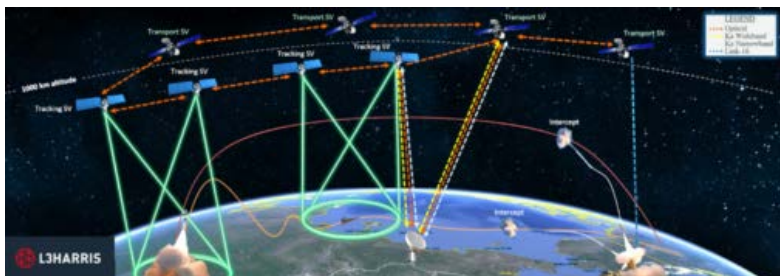


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L3HARRIS TECHNOLOGIES TO DEVELOP PROTECTIVE, END-TO-END, SATELLITE SYSTEM FOR SDA



L3Harris Technologies (NYSE:LHX) will develop and integrate an end-to-end satellite system under a \$193 million firm fixed-price contract for the Space Development Agency (SDA) — L3Harris will support the agency with technology that will protect against advanced missiles, such as hypersonic.

Total period of performance runs through 2025 and covers delivery of four space vehicles for launch within 24 months. L3Harris will develop wide field-of-view mission payloads, various space communication and network solutions, and inter-satellite optical links on the vehicles.

L3Harris is prioritizing investments in end-to-end satellite solutions in spacecraft, payloads, ground software and advanced algorithms. L3Harris also supports the Missile Defense Agency's Hypersonic and Ballistic Tracking Space Sensor and the U.S. Space Force's Overhead Persistent Infrared Satellite Program.

Executive Comment

"L3Harris has brought a different perspective to this mission including our experience as a responsive space prime and decades of electro-optical and infrared payload development," said **Ed Zoiss**, President, Space and Airborne Systems, L3Harris. "We understand the mission and the need to move quickly, which we're able to do by drawing capabilities from across the company."

AUSTRALIAN FUNDING BOOSTS SILENTIUM DEFENCE'S SPACE TRAFFIC RADAR PROJECT

Silentium Defence has secured a \$3.2 million contract from the Australian Department of Defence to advance, deploy and demonstrate its passive radar system for monitoring traffic in space.

The funding comes in the \$28 million latest round of industry grants from the Defence Innovation Hub.

Designed and developed in Adelaide, South Australia, Silentium's MAVERICK S-series is the first commercial-scale passive radar system for surveillance of space and will provide persistent detection and tracking of objects in LEO to support space traffic management.



The Silentium Defence MAVERICK S-series passive radar system for surveillance of space.

The Silentium Defence MAVERICK S-series passive radar system for surveillance of space.

The system requires no spectrum allocation to operate and it can detect and track objects and measure rate of movement in low earth orbit regardless of weather, visibility, or time-of-day.

The Wingfield-based company also announced in June it would lead a project to build a multi-sensor space observatory in remote South Australia. That project, in collaboration with Western Sydney University, was also awarded \$1.46 million through the Australian Space Agency in June.

Silentium Defence CEO

Dr. **James Palmer** said the latest contract win showed that "Defence recognizes the risk posed by the increasingly congested and contested space domain.

Satellite systems are vulnerable to space debris and advanced counter-

space capabilities which can deny, disrupt and destroy our space-based systems. Safe and assured access to this critical domain is predicated on availability of high-quality, real-time data to inform decision making. That is what the MAVERICK S-series will deliver, and we're delighted to further advance the system using local skills and local technology with support and input from Defence."



Silentium Defence Co-Founders Simon Palumbo (left) and Dr James Palmer.



The contract will see Silentium Defence move from its successful completion of Phase one to the start of Phase two deployment under the Defence Innovation Hub program.

The observatory is expected to be completed next year and is being built near the River Murray town of Swan Reach, 160 km northeast of Adelaide and on the edge of South Australia's only officially sanctioned International Dark Sky Place.

He said the passive radar would be powerful but low-power, accurate and agile enough to deliver a transformative capability for the Australian Defence Force and its allies.

Another South Australian company, Prism Systems, also received a \$925,000 grant in the funding round towards developing and demonstrating an integrated capability solution for the Royal Australian Navy. The innovation seeks to improve the efficiency and effectiveness of ship and aviation system integration flight trials through automating processes, analysis, recording, and reporting of data.

South Australia is also home to major Tier 1 defence companies and several emerging space startups, including *Fleet Space Technologies*, *Inovor Technologies* and *Myriota*.

Minister for Defence Industry *Melissa Price* said the latest contracts provided Australian businesses with opportunities that could enhance defence capability. The Australian Government's goal is to triple the size of the nation's space sector to \$12 billion and create an extra 20,000 jobs by 2030.

News story is courtesy of Andrew Spence, THE LEAD

VIALITE'S NEWEST FOR GOVT/MILITARY, MIL-AERO RF OVER FIBER LINK

ViaLite Communications has launched a Mil-Aero 10 MHz to 6 GHz RF over Fiber Link Pair which are produced for various branches of the military. The new products' design and features have been specifically tailored for demanding countries' air force and navy applications, army telemetry systems, signals intelligence (SIGINT) deployments, tethered aerostat and drone applications, plus multi-service military electronic warfare systems; where fiber is an essential replacement to coax.

As one of ViaLite's most versatile RF over fiber links it covers bands from HF, VHF and UHF through to telemetry and SATCOM P-, L-, S- and

C-bands. It also offers the best Spurious Free Dynamic Range (SFDR) performance in its class, making it ideal for high bandwidth applications or where the application has a large range of RF signal powers. The link is further enhanced by a low noise figure (NF), optional gain and 1 dB compression points (CP).



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Supporting distances of up to 50 km, the Mil-Aero link is available in rack chassis card or OEM module format, including ViaLite's new black OEM design which is outdoor rated.

All formats come with the industry's longest five-year warranty as standard providing protection and reassurance for customers.

Craig Somach, ViaLite Director of Sales, said, "I am very pleased to be supporting our Mil-Aero customers with this new and exciting solution that exceeds current solutions in almost every key category related to SFDR, NF and 1 dB CP. The feedback from our users has been very positive and consistently shows the new ViaLite Mil-Aero Link Pair to be setting a new design standard of higher electrical performance and mechanical integrity, along with superior quality and reliability."

NSS SUPPORTS US DEPARTMENT OF COMMERCE TO MANAGE NON-MILITARY SSA DATA

The National Space Society (NSS) strongly supports the decision by the National Academy of Public Administration (NAPA) to recommend, in line with the 2018 Space Policy Directive-3 (SPD-3), that the Department of Commerce be responsible for publicly releasing non-military Space Situational Awareness (SSA) data as part of a new responsibility for Space Traffic Management (STM).

NAPA also agreed with SPD-3 that the [Office of Space Commerce \(OSC\)](#), currently in NOAA, be elevated to the Office of the Secretary of Commerce

and urged Congress to pass authorizing legislation for the move along with an annual funding increase for OSC from its usual \$1.8 million to \$15 million.

Safe, efficient and effective space traffic management is an increasingly critical part of the new space economy and national security. With the cadence of launches picking up and ever-increasing orbital activities, nimble management of American assets in space is critical.

Crew safety is, of course, the top consideration; however, situational awareness of foreign operations and avoiding collisions with the masses of orbital debris that surround our planet is now even more challenging than ever. NAPA's recommendation goes a long way toward addressing these concerns.

Executive Comments

NSS EVP [Alfred Anzaldúa](#) remarked that "NAPA's recommendation, which came after carefully considering the relative capabilities of NASA and Departments of Defense, Commerce, and Transportation, breaks a stalemate holding back U.S. capacity for managing space traffic in the face over 8000 tons of orbital debris and a sharp increase in satellite launches. Granting authority and full funding to OSC per SPD-3 recommendations would fill a gaping space management hole and bring about increased collaboration with governments and commercial companies already collecting and analyzing SSA data to supplement the Defense Department's space catalog."

NSS Chair of the Executive Committee [Dale Skran](#) added, "The full empowerment of Commerce would enhance SSA and STM capability worldwide, and with that, United States space leadership. Under the status quo, no entity has STM authority, and no U.S. administration office can deal with soon-to-emerge space activities like asteroid mining and infrastructure construction in orbit. It behooves us to be prepared for the challenges such activities will bring by carrying out the recommendation of SPD-3 and NAPA."

For more information on the future of human spaceflight, [see the NSS's Roadmap to Space Settlement](#).

TELESAT U.S. TO DEVELOP AS WELL AS ON-ORBIT THEIR DEMO LEO BUSES FOR DARPA

[Telesat U.S. Services, LLC](#), a wholly owned subsidiary of satellite operator [Telesat](#), has been awarded a contract by DARPA (Defense Advanced Research Projects Agency) for the development and on-orbit demonstration of commercial LEO spacecraft buses in a LEO constellation network with robust low-latency communications features as part of [DARPA's Blackjack](#) program.

Following Telesat's initial 2018 contract for system engineering and interface definition under the Blackjack Phase 1 program, Telesat U.S. Services will develop and demonstrate the Blackjack Phase 2/3 Track B technology, including on-orbit testing the capabilities of Optical Inter-Satellite Links (OISLs).



As part of Phase 2, Telesat U.S. Services will deliver two spacecraft buses to DARPA in less than one year for a “risk reduction” flight to test OISL communications with government payloads in orbit and to demonstrate OISL interoperability with different hardware. The Phase 2 base contract represents an \$18.3 million program for Telesat U.S. Services. Subsequently, additional Telesat LEO spacecraft may be procured to fully populate the Blackjack constellation, which represents a total contract value of up to \$175.6 million if all options are exercised.

The Blackjack program is a demonstration of LEO satellites in hybrid commercial- government constellations offering highly resilient space systems, global persistence, low latency communications and rapid technology refresh. These enabling objectives will be accomplished by leveraging commercial space technologies including commoditized spacecraft buses, ground infrastructure and user segments at unprecedented low costs.

The company said the Telesat LEO constellation includes a number of distinctive features that align with the Blackjack program vision, including spacecraft buses with native OISL capability, mesh networking, onboard processing, and a full global network architecture backed by global priority spectrum allocations.

Executive Comment

“This next phase of the Blackjack program will showcase the powerful capabilities that commercial LEO networks bring to a hybrid architecture for government space communications,” said Don Brown, General Manager, Telesat U.S. Services. “With OISLs and advanced networking native to the Telesat LEO constellation architecture, we are uniquely positioned to deliver interoperable mesh connectivity between government and commercial constellations. We look forward to continuing our work with DARPA to prove out the game-changing nature of hybrid commercial-government networks.”

BLUE ORIGIN SUCCESSFULLY COMPLETES NS-13 LAUNCH

Blue Origin has successfully completed the 13th New Shepard mission to space and back and the 7th consecutive flight for this particular vehicle, a record for the firm.

There were 12 payloads onboard including the Deorbit, Descent, and Landing Sensor Demonstration under the NASA Tipping Point partnership. The lunar landing sensor demo was the first payload to be mounted on the exterior of a New Shepard





booster and tested technology designed to achieve high accuracy landing.

This will enable long-term lunar exploration, as well as future Mars missions.

Key Mission Stats...

7th consecutive successful flight to space and back for this New Shepard vehicle (previous booster completed five consecutive successful flights before retirement).

13th consecutive successful crew capsule landing (every flight in program).

The crew capsule reached an apogee of 346,964 ft above ground level (AGL) / 350,611 ft mean sea level (MSL) (105 km AGL / 106 km MSL).

The booster reached an apogee of 346,563 ft AGL / 350,210 ft MSL (105 km AGL / 106 km MSL).

The mission elapsed time was 10 min 9 sec and the max ascent velocity was 2,232 mph / 3,592 km/h.

The mission carried tens of thousands of postcards from Blue Origin's nonprofit, Club for the Future, some of which include a NASA Artemis stamp.



Executive Comment

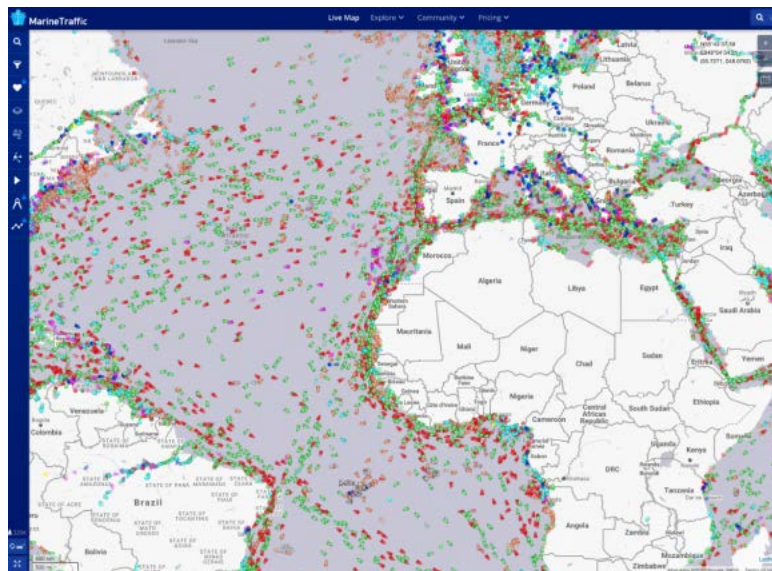
"Today's flight was inspiring. Using New Shepard to simulate landing on the Moon is an exciting precursor to what the Artemis program will bring to America," said Bob Smith, CEO, Blue Origin. "Thanks to NASA for partnering with us, and congrats to the Blue Origin team on taking another step toward returning to the Moon to stay."

ORBCOMM'S AIS CONTRACT WITH MARINETRAFFIC IS EXTENDED THRU 2023

ORBCOMM Inc. (Nasdaq: ORBC) has extended their contract with MarineTraffic through the end of 2023 for ORBCOMM's satellite Automatic Identification System (AIS) data used for ship tracking and other maritime navigational and safety efforts.



MarineTraffic, which has been an ORBCOMM partner since 2013, uses ORBCOMM's satellite AIS data to track real-time and historical movements of ships as well as their arrivals and departures in harbors and ports around the world and also combines ORBCOMM's comprehensive AIS data with positional data from their extensive network of land-based receiving stations to provide actionable maritime intelligence solutions and improve the maritime ecosystem.



By leveraging ORBCOMM's reliable, high-performance AIS service, MarineTraffic helps their government and commercial customers enable maritime domain awareness, search and rescue, environmental monitoring and maritime intelligence applications.



An artistic Rendition of an ORBCOMM smallsat, courtesy of AAC Clyde Space.

In addition, MarineTraffic will explore ORBCOMM's other monitoring solutions as part of their efforts to expand their offering for the shipping industry and provide complete supply-chain visibility.

ORBCOMM continues to advance its AIS business by enhancing its satellite AIS service with two new, next-generation AIS cubesats, which are expected to expand coverage of ORBCOMM's constellation, increase visibility to smaller Class B ships and extend its

polar footprint with launches planned on separate missions within the next year.

In addition, ORBCOMM is working with AAC Clyde Space and Saab to develop a next-generation, space-based VHF Data Exchange System (VDES) satellite, expected to launch in 2022, which will revolutionize maritime communications by providing more extensive global coverage, increased bandwidth and enhanced versatility.

Executive Comments

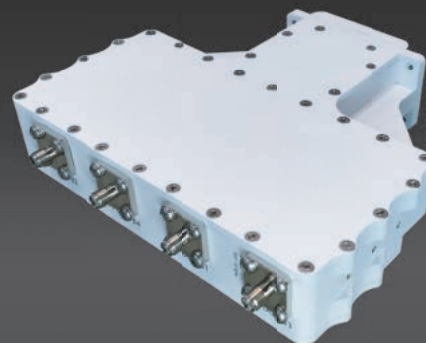
"We are excited to continue supporting MarineTraffic's efforts to improve the overall maritime ecosystem by harnessing the power of ORBCOMM's satellite AIS technology," said **Greg Flessate**, ORBCOMM's SVP and GM, Government and AIS. "As we collaborate on the next phase of our partnership, MarineTraffic will be able to leverage ORBCOMM's industry-leading IoT solutions to enhance the end-to-end view of the global supply chain."

"We are delighted to extend our long-standing relationship with ORBCOMM for another three years," said **Demitris Memos**, MarineTraffic's CEO. "MarineTraffic takes great pride in the collaboration with ORBCOMM and especially appreciates the reliability of ORBCOMM's satellite AIS service."

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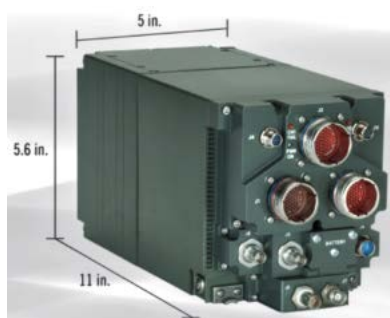
Advance the future

VIASAT ENLISTS NEW LINK16 CAPABILITIES FOR



MISSION-CRITICAL OPS

Viasat Inc. (NASDAQ: VSAT) has successfully integrated Link 16 Cryptographic Modernization (Crypto Mod) capability into its KOR-24A Small Tactical Terminal (STT), ahead of the U.S. Government mandate, to help ensure warfighters have assured access to mission-critical information when using Link 16 communications—regardless of location (air, land or sea) or platform (aircraft, ground vehicle, ship or dismounted warfighter).



The KOR-24A STT is the world's only multi-channel radio capable of performing Link 16 communications in a small form factor, and includes interoperable

functionality to improve communications between U.S. and international coalition partners' military agencies requiring critical information from multiple networks.

Viasat's KOR-24A STT is a software-defined radio (SDR), which allows advancements like Crypto Mod to be accomplished via a software update without the need to take platforms out of service. The Company currently has more than 1,800 STT units in service on a wide variety of fixed-wing and rotary-wing aircraft as well as ground vehicles, expeditionary gateways and maritime vessels across all U.S. military services, special operations forces and five international partners to date.

Executive Comment

"By taking a proactive approach, Viasat's KOR-24A STT successfully achieved Link 16 Crypto Mod requirements ahead of the U.S. government mandate," said **Andy Kessler**, VP and Business Area Director, Next Generation Tactical Data Links business, Viasat. "As the reach, resiliency and relevancy of Link 16 grows, it will be important to expand these capabilities to help U.S. and coalition forces adjust to new mission needs."

Viasat's Trade-in/Trade-up Program

To ensure Link 16 users can easily migrate to a crypto modern solution, Viasat is offering a Trade-in/Trade-up program. Through January 1, 2022, military agencies can trade in any manufacturer's non-crypto modernized Link 16 terminal and receive a discount for the purchase of Viasat's Crypto Mod-enabled KOR-24A STT. The Trade-in/Trade-up program will help ensure warfighters have assured, uninterrupted access to mission-critical information when using Link 16 communications during any critical mission.



Viasat Inc. (NASDAQ: VSAT) has also released a new, advanced configuration of its handheld Link 16 Battlefield Awareness and Targeting System – Dismounted (BATS-D) radio.

This advanced version adds new security features to address emerging and expanded threats associated with the diverse operational use cases and new deployment scenarios where the radio will be used. Accordingly, this configuration has been certified by the National Security Agency (NSA) for immediate use by U.S. General Purpose Forces (GPF), Five Eyes (FVEY) partner nations and coalition forces.

BATS-D is the world's first and only handheld Link 16 radio. This radio bridges a critical gap between air and ground forces by providing warfighters at the tactical edge secure, reliable access to integrated air and ground information for improved situational awareness and enhanced close air support communications. Today, more than 2,000 BATS-D radios have been shipped worldwide and the units are currently in use by U.S. Special Operations Forces.



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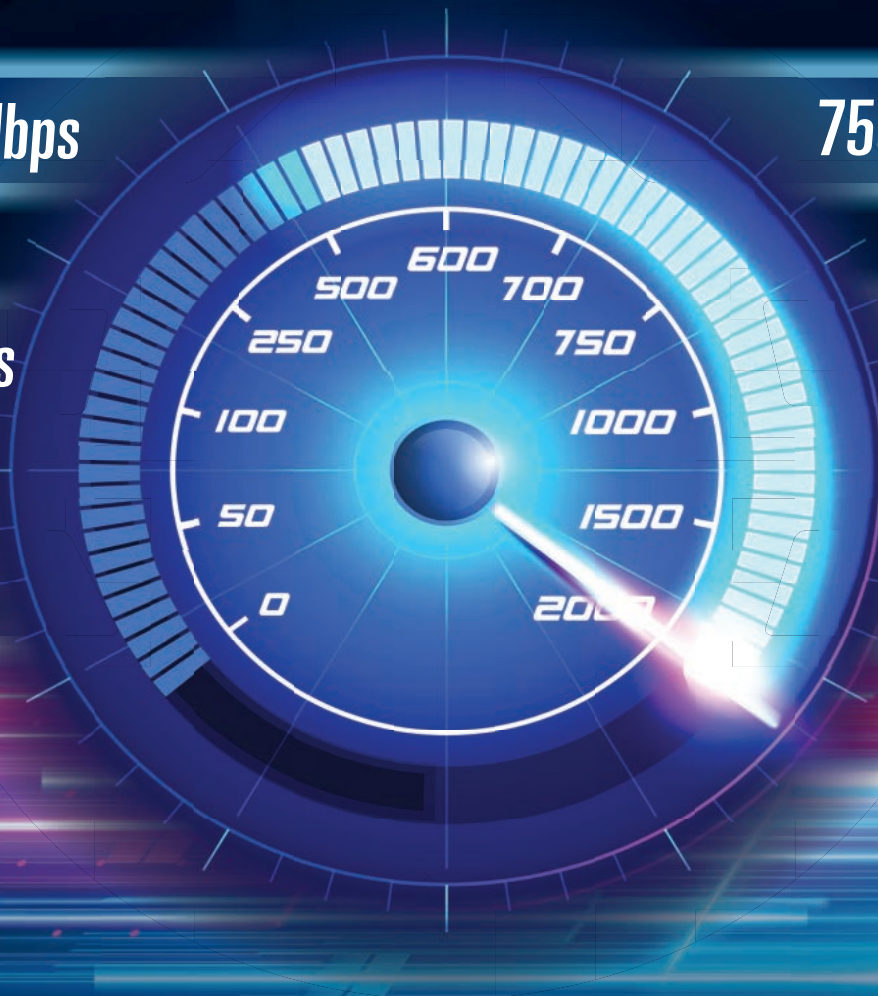
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100Mbps

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The BATS-D handheld Link 16 radio is known to the United States Department of Defense as the AN/PRC-161.

Executive Comment

"The initial success of the BATS-D radios in the field proves this capability to be a true game-changer in military communications," said Andy Kessler, VP and Business Area Director, Next Generation Tactical Data Links business, Viasat. "We've seen tremendous interest to extend the use of the BATS-D radios to new applications and expanded concepts of operation that address specific needs and capability gaps of U.S. and international FVEY armed forces. The availability of BATS-D for GPF and FVEY partner nations will empower more warfighters with secure, interoperable, digitally-aided communications, which ultimately translates into significantly enhanced situational awareness and improved mission coordination across the multi-domain battlespace."

ELBIT SYSTEMS TO PROVIDE TACTICAL RADIOS TO APAC CUSTOMER

Elbit Systems Ltd. (NASDAQ: ESLT, TASE: ESLT) was awarded a contract valued at approximately \$33 million to supply tactical radio systems to a customer in Asia-Pacific — the contract will be performed over a 12-month period.

Under the contract, the Company will equip the customer's Artillery and Infantry Forces with tactical radio systems that also include vehicular, man-packed and handheld configurations. The radio systems feature advanced networking capabilities enabling reliable and secure voice and data communication services over extended ranges.

This contract award follows a recent decision by the customer to equip its Army with additional networked combat solutions from Elbit Systems, including E-LynX Software Defined Radios (SDR) and TORCH-X Command and Control systems.

Elbit Systems' radio solutions have been selected by numerous Armed Forces around the world, including those of Switzerland, Sweden, Germany and Israel.

LEO SPEED: WHEN MILLISECONDS ARE WORTH \$MILLIONS... AN NSR INSIGHT

News story by Carlos Placido, NSR Senior Analyst



"Remember that time is money" wrote Benjamin Franklin in a 1748 book. The concept of opportunity cost believed to trace back to ancient Greek philosophers but popularized by one of the founding fathers of the United States, may nowhere be more critical to business than in the realms of high-frequency trading (HFT).

Planned LEO and VLEO (Very Low Earth Orbit) satellite constellations cannot provision data rates as high as fiber cables when connecting major cities. Yet, speed is also about link delay and a subset of these high-throughput SATCOM initiatives will be able to offer lower latency than fiber across long distances, a situation that could foster wider interest in satellite constellations by financial players.

A large portion of trading today is happening between computer servers with sophisticated algorithms that trade hundreds of thousands of times a second, seeking to repeatedly make small amounts of profits over tiny periods of time. Stock price is subject to constant change, leading to arbitrage opportunities that HFT algorithms seek to quickly capitalize on via speed of execution. Whoever accesses information first has an enormous advantage in speculative markets so, in the age of cloud computing and artificial intelligence, promptly leveraging data can provide a solid competitive edge.

Disregarding the controversies around HFT including market-crash risks derived from relying too heavily on computers that play robot wars and make snap decisions on behalf of humans, it can be plausibly argued that a competitive edge of 10 milliseconds is worth millions of dollars for hedge funds and other financial trading stakeholders. Can LEOs indeed provide lower latency than fiber?

Let us benchmark satellite and fiber link delay between two of world's most connected financial districts: New York City and London. It is a fact that light travels faster in vacuum so based on NSR's Non-GEO Constellations Analysis Toolkit, even the shortest-path, "great

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LEO Constellation with Inter-Satellite Links (ISL)



circle" submarine fiber connection between New York and London has 28% higher propagation delay than a LEO constellation with satellites orbiting at an altitude of 550 kilometers (or lower), provided satellites have inter-satellite links (ISL).

A theoretical shortest-path fiber connection between NYC and London is 5,577 km (3,465 miles) long (assuming Earth radius of 6,378 km). Over such minimum distance, fiber cannot deliver round-trip latency below 55 milliseconds due to fiber's light refraction index, which essentially makes light travel around 40% slower than in vacuum. Indeed, recorded latency metrics (PINGs) between NYC and London across commercial submarine fiber cables consistently show a round-trip delay floor of 70 milliseconds. Commercial fiber cables have multiple hops and network nodes so rarely run along "great-circle," shortest paths between two end points.

Nevertheless, there is a fiber-optics network implementation with ultra-low latency purposely built to target financial players that achieves the lowest possible delay, close to the theoretical limits: GTT's acquired Hibernia Subsea cable route provides a round-trip latency of just under 59 milliseconds between New York's NY4 and London's LD4 exchange data centers.

A LEO satellite constellation with orbits at an altitude of 550 km can be 12 milliseconds faster than fiber optics (round trip propagation latency). This is a theoretical benchmark that ignores jitter (satellites are on the move) and processing delay added by active equipment (such as demodulating/remodulating signals) but note that if the satellite network can be configured in cut-through mode across ISLs to minimize processing, the delay introduced by the two end point modems can be negligible.

As an example, using Datum's performance calculator (actual satellite modem implementation) a DVB-S2X Carrier at 155 Mbps with 64K FEC Block introduces only 0.3 ms end-to-end. Thus, even multiple link legs (with different ModCods) could result in a negligible FEC processing latency.

Alternate Satellite Topologies

Interestingly, when running alternate satellite and hybrid satellite-fiber scenarios on NSR's Non-GEO Constellations Analysis Toolkit, it can be found even without ISLs, a 550 km or lower altitude constellation shell may still beat fiber optics' shortest-path propagation latency by a small margin – assuming no terrestrial interconnect segment.

AMPLIFYING SATELLITE COMMUNICATIONS

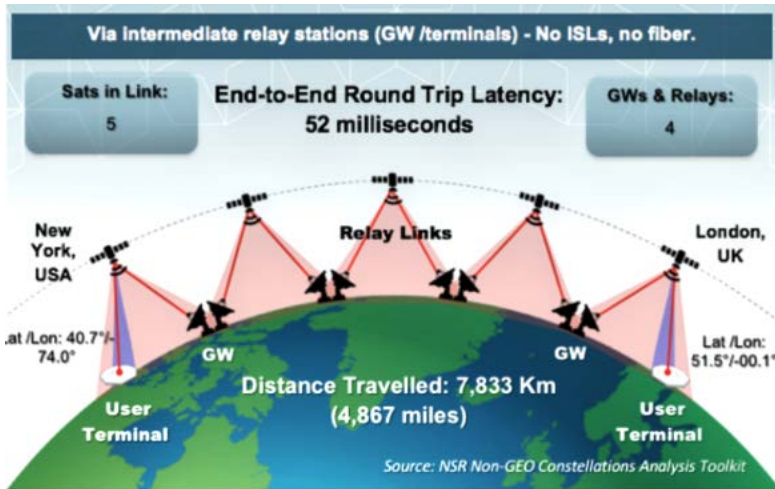
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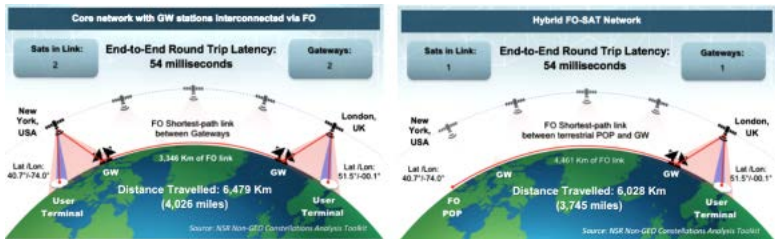
INTRODUCING

The New 160W Ka-Wideband GaN BUC

This “ground bounce” scenario, as coined by Elon Musk, assumes use of intermediate “relay stations” (either plain Gateways used as “pivots” or user terminals with peer-type interconnect capabilities). Note that the NY-London example may not be the best example for such particular scenario given difficulties in deploying relay stations in the middle of the Atlantic Ocean but it paints the picture.



Even classic “Hub & Spoke” SATCOM network topologies employing terrestrially interconnected gateway stations at one or two ends could -in theory- provide lower propagation delay than fiber; albeit by small margins for the 550 km altitude case. Given delay variations introduced by satellites on the move, these topologies may not provide much advantage in practice, so ISLs will be key.



The idea of pushing the limits by leveraging alternate technologies to achieve the lowest possible link latency is not new. This is one reason why microwave links connect the Chicago and NY stock exchanges but LEOs and VLEOs could extend such ultra-low latency capabilities to distant exchange sites. There is, interestingly, a past satellite attempt: LeoSat, which in 2019 needed to go back to the drawing board to reduce the constellation’s price tag, saw the opportunity and announced in 2016 that it had entered into an agreement with an (undisclosed) globally operating financial trading company with offices worldwide.

The analyzed NYC-to-London “fast LEO lane” is one example involving two large financial districts, but consider the implications for the interconnection of other major stock-exchange cities that are

further away from one another: Tokyo, Shanghai, HK, Frankfurt, Milan, Mumbai, Seoul, Sydney, Sao Paulo, Singapore, Moscow and other important trading cities. For these cities, the latency gap between fiber and LEOs to reach Wall Street is even higher.

“Time is Money” so the low latency of LEO and VLEO satellite constellations can have important business implications for latency-sensitive markets. High Frequency Trading (HFT) is a relevant application given the importance of ultra-low latency to the world of algorithmic-based buying and selling of shares, where a competitive edge of 10 milliseconds may be worth millions.

NSR’s **Non-Geo Constellations Analysis Toolkit** is an assembly of flexible, configurable and easy-to-use quantitative models that x-ray and benchmark leading LEO/MEO high-throughput initiatives at architectural and business layers. The toolkit provides a data-driven, unbiased vehicle for deep-diving into the inexorably intertwined technical and business aspects driving bandwidth supply, addressability and feasibility of leading mega-constellations, and their competitive standing versus terrestrial networks.

All LEO scenarios displayed in this article assume 550 km orbital altitude and a minimum antenna elevation of 40 degrees, which is another important factor when benchmarking constellations. Lower antenna angles (such as 25 deg. as proposed by Starlink for the initial phase) may have visibility constraints but can: 1- Reduce number of Gateways or relays; 2- Reduce traveled distance and delay. Thus, the latency gap vs. fiber goes up, particularly for the “ground bounce” case. NSR’ Non-Geo toolkit simulation for such scenario is not included in this article to avoid confusion but, assuming 25 deg. elevation, the “bounce” scenario’s latency is reduced from 52 to 43 milliseconds (interestingly same as “ISLs scenario” with 40 deg. elevation)

Mr. Carlos Placido is an independent consultant and senior analyst with more than 20 years of international experience in telecommunications and entertainment. Joining NSR in 2007 with focus on emerging technologies and satellite markets, he serves as a regional and IP applications expert on satellite communications and regularly provides his analysis and strategic assessment to NSR’s consulting practice. He has conducted numerous analytical and management projects, spanning from global market research studies for NSR, to strategic assessment of emerging technologies, to business development support, R&D and project management. Until 2004, he led a service development team at INTELSAT, where he was responsible for identifying and validating future SATCOM uses of emerging video and IP data technologies. Mr. Placido is also a regular contributor to specialized industry publications and administers Satcom Post, an online professional knowledge-sharing platform. He holds an engineering degree (BS+MS) from the University of Buenos Aires and an MBA from the University of Maryland, Robert H. Smith School of Business.



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WAVESTREAM CELEBRATES 20TH ANNIVERSARY & RELEASES NEW MATCHBOX 50W GaN BUC

Wavestream has introduced the company's next generation solid state power amplifier (SSPA) for operation with GEO and NGSO constellations in the Wideband Ka-band category.



Wavestream's new Matchbox 50W Wideband Ka GaN BUC is the next generation of the world's most widely deployed solid state amplifier built at this power level.

Wavestream's next-generation Matchbox 50W Ka Wideband SSPA operates in both commercial and military frequency ranges. Existing military applications using narrow-band Ka-Band amplifiers will benefit from the wideband product that has been designed as a drop-in replacement, allowing immediate access to commercial NGSO and GEO satellite constellations.

The product features a very compact light weight design and provides the same power as its previous generation, but with 52% less volume and a 60% reduction in weight.

Executive Comment

"Wavestream is pleased to reinforce our technological superiority and leadership in the Wideband Ka-band SSPA category as we answer our customer's demands for broadband connectivity over both GEO and NGSO constellations," said **Bob Huffman**, General Manager at Wavestream. "As Wavestream celebrates its 20th anniversary this year, I am delighted to report that we have fielded over 40,000 products since our inception, for both commercial and military markets."

OPTICAL COMMS EARTH STATION TO BE BUILT IN WESTERN AUSTRALIA



An optical communications station capable of receiving high-speed data transmissions from space is set to be built in Western Australia and will be installed by [The University of Western Australia](#).

The advanced communications ground station will be able to receive data from spacecraft anywhere between LEO and the surface of the Moon. It has the potential to support ground-breaking space projects, including NASA's Artemis mission to land the first woman and next man on the Moon by 2024.

This is a joint initiative of UWA's Astrophotonics Group, which is part of the [International Center for Radio Astronomy Research \(ICRAR\)](#), as well as the [ARC Centre of Excellence for Engineered Quantum Systems \(EQUS\)](#) and UK industry partner [Goonhilly Earth Station](#).



Goonhilly Earth Station.

The ground station was launched to coincide with the International Astronautical Congress. It will be part of a larger Australasian optical ground station network, led by the Australian National University, and with partners in South Australia, and New Zealand.

The station will use make use of a 0.7 meter observatory-grade optical telescope donated to ICRAR by Perth local Colin Eldridge. It will be fitted with advanced atmospheric-noise suppression technology developed at UWA.

The station will be connected to Goonhilly's supercomputer data center in Cornwall via high-speed fiber. Goonhilly handles data traffic and supports secure communications links for the world's major satellite operators, including Intelsat, Eutelsat and SES Satellites. The company is also a partner in the European Space Agency's Lunar Pathfinder Mission, which is scheduled to launch in 2022.



The 0.7 meter optical telescope donated by Colin Eldridge that will be used for the ground station.

brought us the voice of Neil Armstrong when the Apollo 11 mission landed on the Moon in 1969. Free-space optical laser communications has several advantages over radio, including significantly faster data rates and hack-proof data transfer. It's the next-generation of space communications, and it's likely to be how we'll see high definition footage of the first woman to walk on the Moon." He noted that WA's ground station would help launch Australia's space communications capacity, stating, "This will cement Australia's position as a leader in optical data transmission, and position the nation to tap into the multi-billion-dollar space communications market."

EQUS Director, Professor **Andrew White**, said the project, which could be the first 'on-sky' optical communications ground station in the Southern Hemisphere, was a prime example of fundamental research delivering real-world outcomes. He said, "EQUS delivers major impacts by encouraging and enabling our people to translate their research into tangible technologies and applications. We are building a culture of innovation, translation and commercialization among quantum science researchers in Australia. In addition to space communications, the ground station could also be used for applications ranging from cutting-edge fundamental physics to precision earth science and resource geophysics."

Goonhilly Chief Executive **Ian Jones** said he was delighted to join forces with UWA, ICRAR and EQUS to establish an optical communications satellite ground station in Western Australia. He said, "We've been at the forefront of satellite communications since the start of the space age, and this is driving it into the next generation of systems and technologies to support the enormous data volumes emanating from space missions. This data arises from science and other missions and, in the future, will come from Lunar and Mars missions that involve remote operations, robotics and AI. We're proud to be joint trailblazers in the practical implementation of coherent optical communications."

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The Global Mercy, the newest and the world's largest civilian hospital ship, will leverage SES Networks' Signature Maritime Solution, bringing about a substantial change in diagnostics and treatment onboard for its patients. The high-performance connectivity services will enable the Global Mercy to fully implement remote viewing for a compact digital scope and CT scanner that enables specialist pathologists to remotely diagnose a raft of complex, life threatening, or deadly diseases onboard.

Mercy Ships will also leverage the connectivity to expand services and leave local communities with sustainable skills to care for their own. The Global Mercy medical staff will have the possibility to run live HD video training sessions from the operating room on board to deliver unparalleled medical training and support.

SPACE FOUNDATION'S NEWEST SPACE REPORT NOW AVAILABLE

In the newest quarterly issue of The Space Report, Space Foundation, a 501(c)(3) global space advocate for 37 years, announced that space investment in Q3 2020 gained strength with more than \$6 billion gained through acquisitions, buyouts, and



private equity financing.

Acquisitions and buyouts in Q3 totaled more than \$3.3 billion in disclosed value across 17 announced transactions, significantly outpacing the 13 transactions and \$265 million in disclosed value

announced in Q2, according to analysis by Quilty Analytics published in The Space Report 2020 Q3. In private equity and venture capital investments, the Q3 total reached nearly \$2.7 billion in 25 financings compared to Q2's \$410 million raised in 32 transactions, Quilty analysis found.

Additionally, The Space Report 2020 Q3 includes analysis of 2019 commercial space revenue, and annual data there also shows gains over the prior year, as well as strong 10-year performance figures. Commercial space revenue, which represents about 80% of the global space economy, climbed 6.3% from 2018, growing to \$336.89 billion. Over 10 years, the increase was 77.8%.

Commercial space products and services remained the largest percentage of the sector, and in 2019 those totaled \$217.72 billion. Though up only 1.7% from the prior year, the sector was up 113% from its 2010 total of \$102 billion.

In commercial infrastructure and support industries, revenues were up 16.1% compared to 2018, finishing at \$119.17 billion in 2019. The decade's change was more modest compared to space products and services, rising only 36% since 2010. Some 2019 industry highlights include...

Satellite manufacturing reversed a downward trend in 2019 and is expected to remain strong through 2020. Airbus and Thales Alenia Space captured 10 of 17 orders in 2019, and this past summer won significant contracts valued at more than \$1 billion with ESA and the UK, fueling confidence in the continued strength of the market.

Ground stations and equipment generated more than \$112.45 billion, and a 10-year forecast from the European Global Satellite Services Agency predicted that the sector will grow significantly.

Earth observation satellite revenue also climbed to more than \$3 billion. Almost 32% of revenue came from the sale of raw data collected by commercial satellites.

Approaching the 20th anniversary of continuous human habitation of the International Space Station, and with expected private launches by more commercial launch providers, The Space Report also examined some of the numbers behind nearly 60 years of space travel. Since 1961, 580 people from 41 countries have launched into orbit, according to the Association of Space Explorers (ASE). That's an average of 9.8 astronauts per year. In the nearly 60 years since astronauts have been launching into space, 62% have been U.S. astronauts. Russian cosmonauts, however, have spent the most cumulative time on the ISS with a combined 36.6 years.

Commenting on the release of The Space Report 2020 Q3, Space Foundation CEO *Tom Zelibor* shared, "Numbers such as these reflect the strength and enduring growth of the global space economy. Investors, entrepreneurs, and consumers can find confidence and opportunity in multiple sectors of the space economy,

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Satellite Transportable Terminals (STT) provide critical infrastructure in the US Army's Tactical SATCOM network. They are good candidates for integration to the flexible management interface solution.



ENABLING FIGHTING SATCOM THROUGH A DIGITAL GROUND

By Chris Badgett, Vice President of Technology, Kratos Space

"The ultimate goal is simple: give the battlefield commander access to all the information needed to win the war. And give it to him when he wants it and how he wants it..." General Colin L. Powell

Operation Desert Storm propelled the Department of Defense (DoD) to realize the value of satellite communications and the indispensability of commercial SATCOM for modern combat. At that time, only 20 percent of all satellite communication services were commercial. By the time of Operation Iraqi Freedom, commercial services accounted for 80 percent of SATCOM.

Unfortunately, despite this growth, multiple organizations independently pursuing their own mission needs produced a multitude of ground based proprietary satellite communication solutions, which in turn created a lack of interoperability between different commercial services and the armed forces.

Those same proprietary solutions remain roadblocks to a dynamic SATCOM infrastructure supporting communication for an evolving military landscape.

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Unfortunately, in spite of this growth, multiple organizations independently pursuing their own mission needs produced a multitude of ground based proprietary satellite communication solutions, which in turn created a lack of interoperability between different commercial services and the armed forces. Those same proprietary solutions remain roadblocks to a dynamic SATCOM infrastructure supporting communication for an evolving military landscape.



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LEO, MEO and GEO is ubiquitous. This requires a move away from proprietary stove-piped systems to flexible, scalable, sustainable and interoperable, and most of all dynamic SATCOM technologies. It has to enable resiliency and expandable SATCOM capacity where it is needed, when it is needed.

This means terminals that can automatically switch between different satellites and warfighters who can seamlessly communicate to networks outside of their domain. If terminals are jammed, there must be a system in place that can automatically locate and help switch to reliable communication links. If redundant terminals or gateways are not available, alternative waveforms must be automatically accessible and applied.

Shifting from closed, proprietary hardware to a virtualized, standards-based software ground infrastructure allows automatic synchronization with digital assets both on the ground and in space. It changes the paradigm by delivering abilities to re-provision hundreds of satellites, thousands of beams, and millions of services in response to changes in demand, interference and threat.

This technology already exists and is operational today in the terrestrial telecommunication world, and that same approach can be applied to SATCOM. For instance, in the terrestrial IP world, communication services are created and moved dynamically upon new service demands at the speed of machine-to-machine API and standards.

There are many advantages to software based systems over proprietary hardware based systems, starting with specialty hardware replaced with commodity infrastructure. It improves speed of deployment and speed to stand-up new services. It allows you to try new things and experiment without long development cycles.

Software allows you to scale fast and fail fast, offering agility, reliability and better security. And notably, it creates a dynamic ability to move services and virtual assets around the network to where they are needed on demand.

these programs work in the most effective way possible, creating an interoperable environment where communications paths can be deployed dynamically and automatically versus numerous manual configurations with long delays.

The Fighting SATCOM enterprise requires a dynamic architecture using principles of software defined networks and virtualization to unify stovepipe requirements, driven by mission unique circumstances. Such architecture is already being designed.

The United States Space Force (USSF) has defined a vision called the Fighting SATCOM Enterprise that enables interoperable SATCOM technologies. It has several critical elements...

(1) a Command and Control (C2) management system to address and manage the enterprise

(2) a global RF Situational Awareness Common Operational Picture (SA-COP) that allows one to understand any problems being experienced by the enterprise

(3) "wave-form agnostic" multi-mission capable SATCOM terminals that are flexible enough to automatically implement changes throughout the enterprise, with common operating standards driving interoperability across military and commercial SATCOM partners.

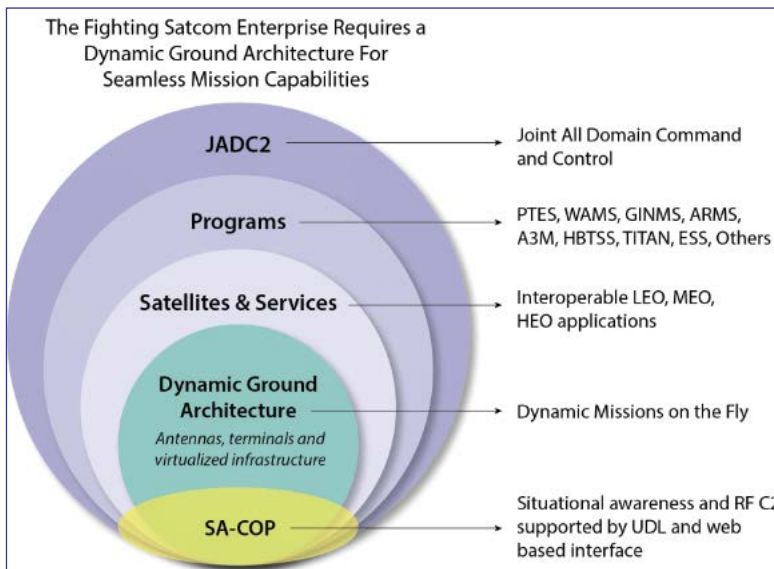
Several Enterprise Management and Control (EM&C) efforts have successfully demonstrated synchronized access to multiple satellites and satellite networks operated by multiple service providers. EM&C is the center of a hybrid architecture enabling a more dynamic ground by integrating disparate capabilities.

EM&C shows that the control of multiple modem types and software versions from within a single Terminal, using the digitization of satellite signals to and from the appropriate antenna, is a key technological enabler for Advanced SATCOM management. Connected to a dynamic ground and informed with SA-COP, the system has a comprehensive mission-management ability that can rapidly plan, optimize, apportion, and monitor SATCOM services as well as detect, locate, assess and resolve SATCOM issues for users.

Unifying Commercial & Military Satellites

Leveraging some of the same advances and investments already in use by commercial industry, the DoD can support interconnectivity without spending additional money on new terminals, hardware or even satellites.

By adopting a common digital ground infrastructure, core capabilities can be connected with a broad span of functions and processes, removing the need for siloed operations. A (predominantly software-based) enterprise architecture can support dynamic



Virtual ground platforms can be unified to serve all programs and deprecate stovepipe systems.

current network and terminals to alternate communications resources with little or no disruption.

Military and commercial satellite communications systems can tie seamlessly into the terrestrial infrastructure, providing assured and resilient communications on demand while Warfighters are on the move and operating around the globe.

Software Defined Networks Allow SATCOM to Operate Dynamically

Starting with digitizing the RF signal and converting it into a format that is standardized and accepted throughout the industry, commercial and military satellite operations can become interoperable and dynamic. In the same way that infrastructure standards transformed the wireless industry and made it interoperable, the satellite ground must adopt infrastructure standards as well.

Early cell phone networks were not interoperable, a Verizon customer could not send a text to an AT&T user — but a demand for expanded connectivity led to the current, remarkably global cellular infrastructure. Because of the open standards deployed by the telecom industry through their experience in the 90s, you can now use a cell

By agreeing to and following common standards, the satellite industry can also introduce its own interoperability capabilities. Digitizing the RF signal to a common standard such as VITA 49 would evolve ground systems to a digital format, enabling a shift from proprietary, purpose built systems to software-defined, virtual systems. As software-defined network platforms become part of the infrastructure, ground systems will become more dynamic. Digitizing the RF signal and building a common architecture approach for management and control of the satellite network leads to a fundamental shift in the industry. Especially now, with advanced cloud processing speed and capabilities, the same approach that allows software-defined networks to work successfully in the IT and telecom world can be adopted to serve the satellite ground needs in both commercial and military operations.

Common Standards Enable Seamless Communication

Fighting SATCOM's Management System supports the planning, directing, monitoring and control of SATCOM. Driven by common standards, it is a tool that will respond to satellite access requests and dynamically allocate SATCOM resources.



Common standards allow global connectivity for the cellular market.

and orchestrate virtual network functions and services developed by military or commercial partners. The design avoids vendor lock to any vertically integrated, sole-source solution, while allowing multiple vendors to innovate on compatible waveform-agnostic terminals, Gateways and networks. Rendering the power to quickly instantiate services on demand, it underpins the ability to communicate through multiple ground entry points or government Infrastructure as a Service (IAAS) or Platform as a Service (PAAS).

Automated deployment has been proven to capably spin up a new satellite command and control stack in less than 10 minutes, compared to weeks or longer. Military satellite communications are no longer tied to permanent ground stations, nor are they tied to specific satellites, but instead are limited to network infrastructure decisions such as bandwidth, connectivity, and trust.

Situational Awareness Common Operational Picture (SA-COP)

In the Fighting SATCOM Enterprise, the SA-COP, which is itself based on open standards, gathers all the information from sensors and satellites into one database across stovepipe programs, DoD terminals, user services, frequencies and orbits. Because of that, it will be able to tie into related network resources, with the ability to distribute data to other domains' C2 systems governed by the same standards in order to execute integrated, multi-domain planning and responses.

The SA-COP, initially developed for the Enterprise Management and Control (EM&C) efforts, reflects a dynamic 3D visualization of the global enterprise, including satellites, beam footprints, and user groups. It can be customized, allowing for the filtering of information

etc. It gives the health, status and performance of satellite communication links and associated terrestrial networks in real-time, integrates Kratos SATCOM Enterprise Management tools with one view and allows interoperable situational awareness, mission orchestration and ground control capabilities.

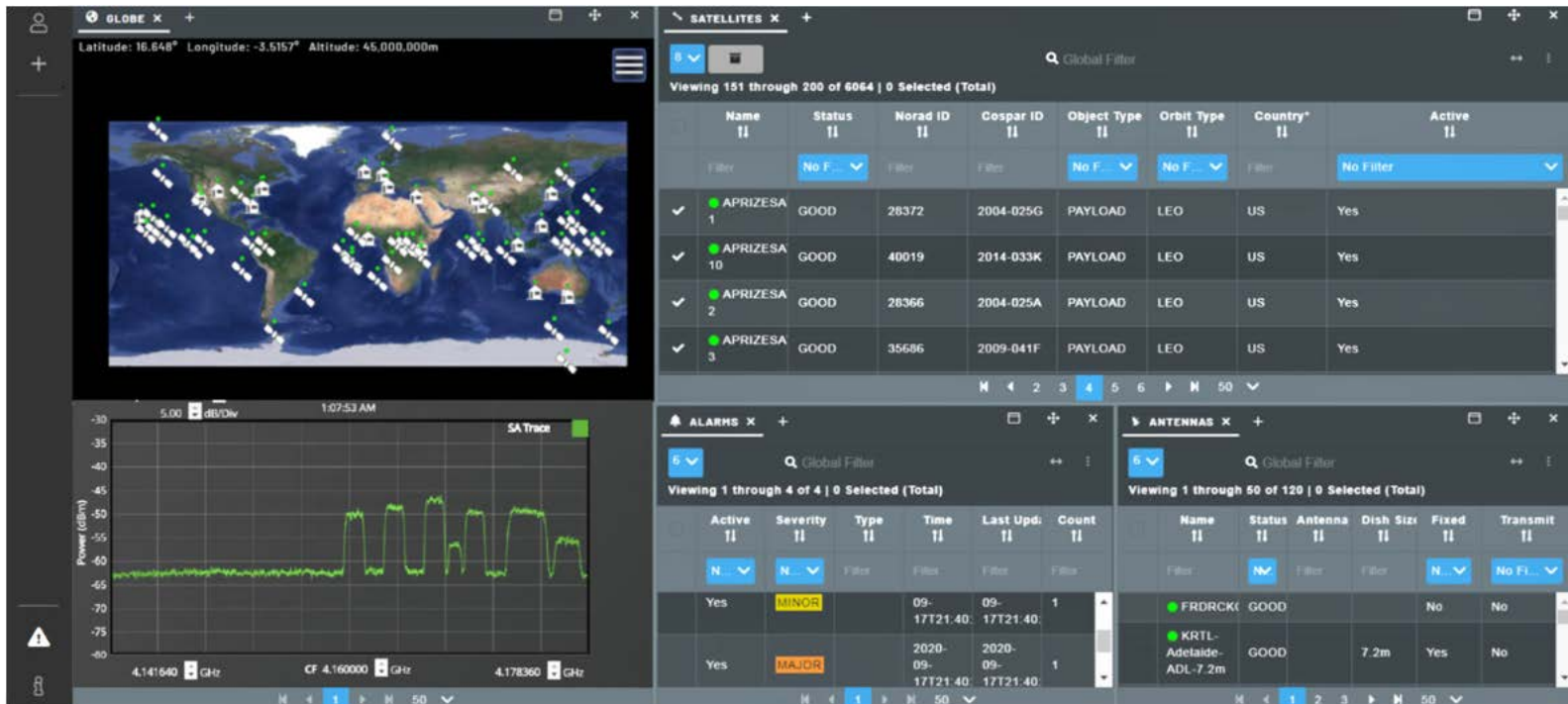
Terminal and User Level Flexibility

The Department of Defense (DoD) currently maintains thousands of terminals with approximately 135 different designs. By applying the Flexible Management Interface (FMI) at the monitor and control interface, any of those terminals can be adopted for further use under the Fighting SATCOM Enterprise Vision. The FMI definition allows existing military ground terminals to flexibly use military and commercial SATCOM.

One key potential application is integration with the Protected Tactical Enterprise Service (PTES) when this system becomes available in 2024-2025. The PTES system manages the Government's next generation Protected Tactical Waveform (PTW) capable networks over WGS and commercial satellites.

The FMI can be extended to support the terminals hosting the Air Force – Army Anti-Jam Modem (A3M) and/or the Wideband Anti-Jam Modem System (WAMS), which are two modems hosting the Government's next generation Protected Tactical Waveform (PTW). The open standards design allows seamless connection of future terminals between PTES and other SATCOM networks.

This approach supports the underlying objectives of Joint All Domain Command and Control (JADC2) and the Air Force's Advanced Battle Management System (ABMS).



Global sensors for the RF SA COP will provide data to the United Data Library (UDL) and be leveraged by all commands.

of capabilities that get the right information to the right people at the right time. Having standards based architecture that is layered and extensible, permits user services to be created on demand and avoids congested spectrum. It gives the ability to fight through jamming issues with dynamic, resilient links and automatically respond to security vulnerabilities. It reduces development risks and helps ensure the government has significantly longer operational life-cycles.

Keys to Fighting — SATCOM's success include maximizing the use of previous U.S. commercial and defense industry sector investments. This has resulted in readily available standards and commercial off-the-shelf (COTS) products to avoid redundant investment in mission-specific software or terminal hardware. These innovative technologies are mature, secure, and can contribute to the wider Multi-Domain Operations (MDO) architecture. ~Velos

Open Architecture Platform Supporting Interoperability

Kratos is in a unique position to support the USSF vision of a fighting SATCOM with common digital ground infrastructure elements supporting military and commercial satellite partners - both on the ground and in space. Warfighters will be able to seamlessly switch between military and commercial SATCOM. Global connectivity will be available even in environments where one or more signals are denied or degraded. The design elements support joint interoperability with commercial partners and the continued utilization of thousands of legacy terminals.

Through the EM&C efforts, Kratos and its partners have successfully demonstrated synchronized access to multiple satellites and satellite networks, operated by multiple service providers. Kratos has helped design the definition for the database that gathers all the information from sensors and satellites used in Fighting SATCOM Enterprise's SA-COP.

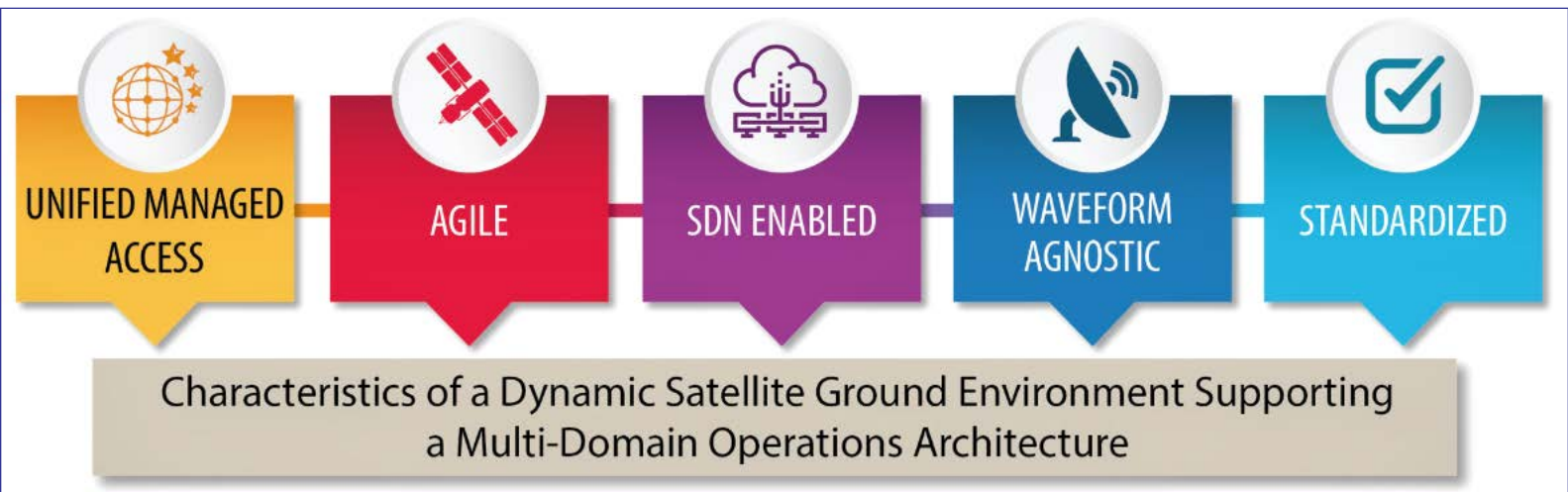
Beyond what is gathered on a program specific basis, the Kratos Global RF Sensor Network gathers commercial SATCOM RF data and populates data with the SA-COP, providing the visualization and management of the space-ground platform from a "single pane of glass."

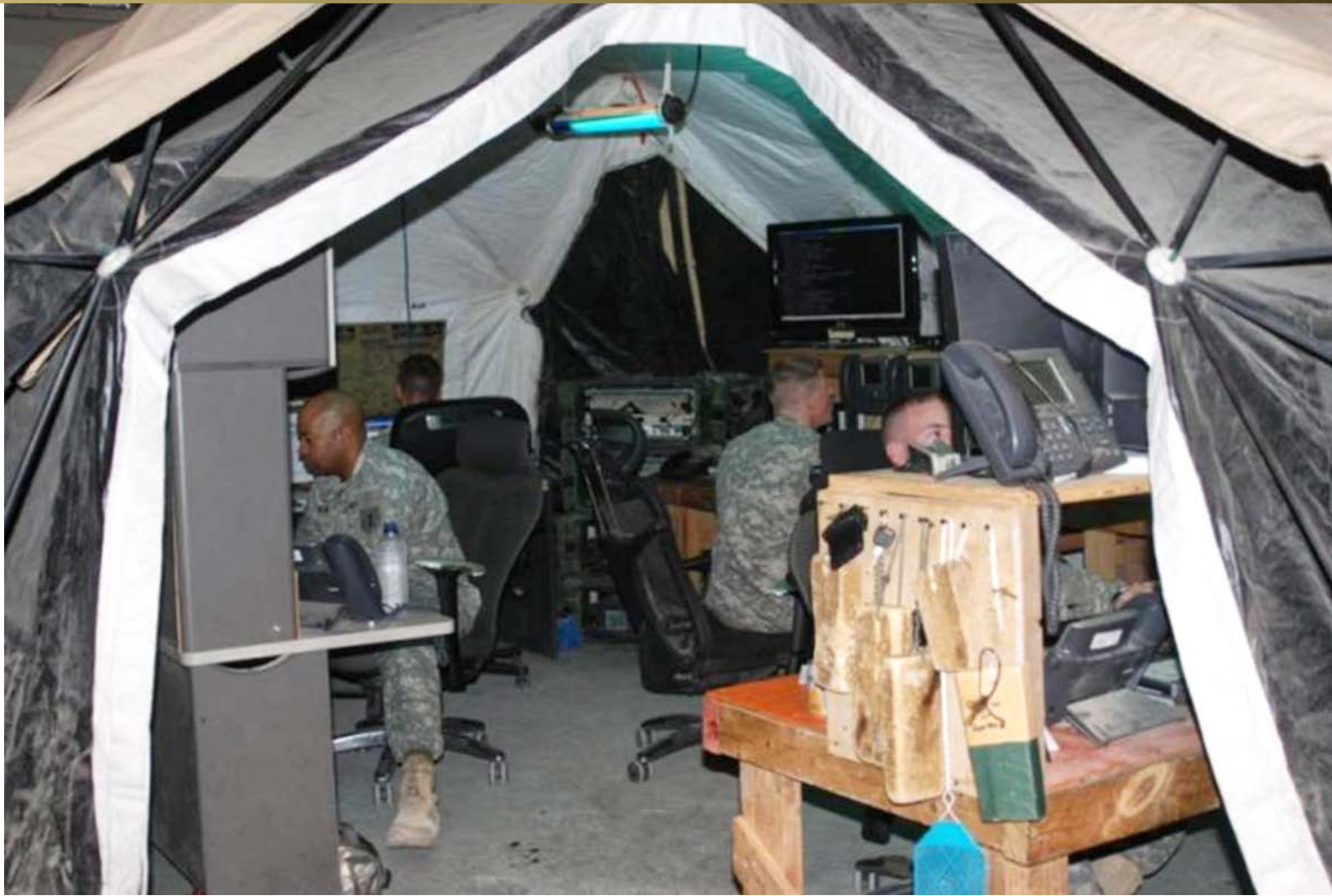
Warrior, GINMS, ARMS, WRMS, TITAN and any number of programs through the same interface. The point being you can integrate all of this data into a single system for a holistic system of systems complete view of the RF spectrum.

Through the EM&C efforts, Kratos and its partners have been actively deploying software solutions that support legacy heterogeneous terminals, allowing them to receive and transport satellite mission data from various satellites and multiple domains. The software works like a translator between the existing proprietary terminal control features and the standards-based FMI. It supports multiple commercial partners' interoperability with MILSATCOM and ties into the EM&C architecture to support agile, path agnostic connectivity.

Kratos brings the benefits of virtualization to satellite networking, providing the necessary efficiency, agility and resiliency that are fundamental requirements to the Fighting SATCOM Vision. Critical elements such as a management system to address the enterprise, a global RF Situational Awareness Common Operational Picture (SA-COP) that allows one to understand any problems being experienced by the enterprise and wave-form agnostic, multi-mission capabilities are all available for integration into current and future programs.

Chris Badgett is Vice President of Technology for Kratos Space. He has been instrumental in designing the capability for the military to take advantage of virtual ground solutions and the ability to securely leverage the power of cloud computing and global antenna networks. Prior to Kratos, Mr. Badgett served in the Air Force Research Lab and Space and Missile System Center enabling technologies for UAVs, datalinks, small satellites and ground systems. Mr. Badgett holds a BS in Electrical Engineering from University of Tennessee and an MS in Space Systems from the Air Force Institute of Technology.





DEFENSE-IN-DEPTH APPROACH IS DYNAMIC GAME CHANGER FOR SATCOM CYBERSECURITY

By Karl Fuchs, Senior Vice President of Technology, iDirectGov + Senior Contributor, MilsatMagazine

Applying cybersecurity in a SATCOM environment requires a layered security approach, or Defense-in-Depth as it is sometimes called. As recognized by the National Security Agency (NSA), Defense-in-Depth is an effective means to protect networks by presenting multiple obstacles for would-be hackers. This approach combines various strategies to mitigate threats, protecting an organization's data and SATCOM network.

The critical layers of a Defense-in-Depth SATCOM network include detect, mitigate, prevent and predict. A review of these layered solutions provides insight to the cybersecurity approach.

Detect

Detection allows the user to discover and identify the existence of a security lapse. In an iDirectGov network, detection centers around the iVantage network monitoring tool, spectrum monitors and

geolocation product.

As part of the Network Management System (NMS), iVantage provides an easy-to-use responsive graphical user interface (GUI) and reports on performance irregularities to an organization's SATCOM network.

Network performance is monitored in iVantage, including in-routes, remotes, applications and the IP packet level. With this information, a network operator can immediately respond to any threats to the security of the network.

Spectrum monitoring tools perform automatic and operator-directed monitoring to detect interferences and unauthorized users, measure carrier and transponder performance, and generate out-of-tolerance alarms. These tools allow the user to effectively measure and analyze the transponder spectrum.

Geolocation allows operators to view real-time spectra for the



detection and characterization of interference. The model 8000 seamlessly transitions from detecting the interference to geolocating the interference with the click of a button. Model 8000 geolocates transmitting terminals quickly and accurately. It locates the interference by taking advantage of the weak replica of the signal that an adjacent satellite will receive. Downlinks for the primary and adjacent satellite are acquired and analyzed to extract precision time difference and/or frequency difference information used for locating the interfering signal. Once the signal has been located, the operator is ready to take the appropriate steps to mitigate.

Mitigate

Mitigation is used to remove or avoid any potential network threats. iDirectGov's Communication Signal Interference Removal (CSIR™) technology and dual-mode and beam choice features mitigate threats to a SATCOM network.

Radio frequency (RF) noise and interference, intentional or unintentional, can degrade a SATCOM network, sometimes rendering it completely unusable. CSIR eliminates an interfering signal from the authorized signal of interest (SOI). With only the SOI's center frequency, bandwidth and symbol rate information, CSIR will monitor and remove an interfering signal in real time. CSIR can remove a variety of unwanted signals, whether they are modulated carriers, unmodulated tones or interference that changes characteristics (such as burst or frequency hopping).

Based on the SOI's information noted above, CSIR can monitor and remove an interfering signal with as little as 1dB of power separation from the SOI. Additionally, CSIR has little to no effect on the signal quality of the SOI.



The 9800 AE Satellite Modem.

As another mitigation tool, dual-mode gives users the benefit of targeted connectivity combined with ubiquitous global coverage. The 9-Series modems can operate on both government owned and commercial networks, giving the user the ultimate flexibility.

Dual-mode is an automatic process when transitioning from one Defense network to

another Defense network. It is also automatic when transitioning from a private government owned network to a commercial network.

When designing SATCOM networks in a mobile environment, the beam strength and the footprint are of the utmost importance, especially in theater. By providing users *Beam Choice*, they can prevent network reacquisition due to a weakening signal or a change of footprint. Operators can manually select the ideal beam for their missions rather than using the automated process.

Beam Choice is not limited to just beams in a Defense network. It also allows for selection of beams in a commercial network for complete global coverage.

Prevent

Preventing security threats moves the battle for security to a more proactive stance. iDirectGov utilizes transmission security (TRANSEC) and Information Assurance (IA) to protect communication signals and network hardware from potential threats.

TRANSEC protects against adversaries who try to obtain information through monitoring the satellite waveforms traveling between remotes and hubs by addressing vulnerabilities in an IP-based VSAT architecture's transmission path. Factors such as increased traffic, terminal spoofing and data interception can all be used to infer classified data. The waveforms and protocols of TRANSEC-enabled networks are specifically designed to appear consistent, regardless of the amount of traffic or the number of active users.

IA refers to managing the risks of processing, storing and transmitting data and the systems used for those actions. IA uses physical, technical and administrative tasks to control these risks. iDirectGov uses a two-pronged approach to IA: one safeguards the servers and a second covers the remotes. By protecting both the servers and the remotes, potential attack surfaces are reduced.

Another prevention tool, Security Content Automation Protocol (SCAP), serves as the configuration standard for the U.S. Department of Defense (DoD) IA program and IA-enabled devices and systems. SCAP services are offered on all servers in an iDirectGov network,

including the NMS, Protocol Processor (PP) and the Global Key Distributor (GKD).

Since 1998, the Defense Information Systems Agency (DISA) Field Security Operations (FSO) has played a critical role in enhancing the DoD's security systems by providing SCAPs. These provide technical guidance to "lock down" information systems and software that might otherwise be vulnerable to a malicious computer attack. iDirectGov's implementation of SCAP standards ensures the highest level of compliance is met. In addition, iDirectGov supports a number of manual configuration changes to meet additional SCAP guidelines, including Red Hat Linux-specific recommendations. Security Readiness Review (SRR) scripts test products for SCAP compliance and are available for operating systems and databases that have SCAPs.

SHIELD, another prevention solution from iDirectGov, identifies vulnerabilities by using a DoD-approved scanning tool called Nessus developed by Tenable. The Nessus scanner identifies vulnerabilities that could allow unauthorized control or access to sensitive data, misconfiguration, default passwords and service vulnerabilities.

SHIELD scans evaluate the 9-Series routers for vulnerabilities that hackers could use to access a system or network. The data is then used to design a Remote Security Bulletin (RSB).

Predict

SAMS™ is a powerful satellite capacity and link resource management tool used for planning and organizing space, ground and network assets that support satellite communications. Using SAMS, satellite traffic planners can manage their network traffic and perform link budget analyses to optimize space assets while meeting data throughput needs. Designed for both fixed and mobile networks, it provides network wide visibility and performance assessment.

When looking at reports, some of the biggest benefits are an increased understanding of risks and opportunities in an organization's satellite network. Reports can enable the streamlining of processes and improve efficiency.

The robust NMS provides automatic alerts and warnings that can help operators anticipate potential attack vectors. Performance stats per network, in-route, remote, application and IP packet level permit effective network management

Outside of the NMS, iDirectGov offers a Bandwidth Timeslot Correlator (BTC) that allows network operators to view and analyze bandwidth and timeslot allocations. The BTC expands Network Operations Center (NOC) capabilities in a Time Division Multiple Access (TDMA) network to enable network operators to manage time slot allocations and to optimize networks to avoid network traffic gridlocks. The software module also provides an automated graphical representation of historical time slot usage and bandwidth for a given network, in-route group or remote. By using historical data, users can

re-define and enhance upstream links for better throughput performance and achieve savings in satellite bandwidth and costs. These report designations are configurable through a user interface. Maintaining a healthy network is one of the most important steps to security and efficiency of a satellite network. Through the iDirectGov Premium iSupport program, a comprehensive network analysis can be conducted in four key phases: customer consultation, data collection, data analysis and report documentation. Through the health check, network conditions are assessed, and recommendations are made for improved efficiency and security.

In Perspective

Implementing a Defense-in-Depth approach to SATCOM cybersecurity to plan, detect, locate, remove, report and deploy mitigation to signal interference allows defense, homeland security, first responders and other government users to have reliable and secure communications to support their critical missions. The idea behind this approach is if one mechanism fails, another checkpoint is ready and waiting to thwart an attack.

Adopting a proactive multi-pronged approach as Defense-in-Depth is profoundly changing the security posture. The inherent security in iDirectGov's solutions protects and minimizes the attack surface from actors that may, intentionally or unintentionally, interfere with lines of communications. Not only can these newest Defense-in-Depth solutions protect defense and government users from the tiniest drops in the "interference pond," they can protect users from the storm of bad actors. It's full speed ahead for secure SATCOM.

www.idirect.gov

Karl Fuchs is the Senior Vice President of Technology at iDirect Governemnt (iDirectGov), a U.S. corporation that is a trusted partner of the U.S.

government and has been for more than 17 years. All its employees are U.S. citizens, with a third being U.S. military veterans and more than 60% holding U.S security clearances.

Fuchs leads iDirectGov's team of federal systems engineers and serves as chief architect for new product integration and specialized technology, including transmission security (TRANSEC), Communication Signal Interference Removal

(CSIRT™) anti-jam technology and Open Antenna Modem Interface Protocol

(OpenAMIP). All Defense-grade products sold by iDirect Government are designed, developed, assembled, programmed and verified within the United States.

Fuchs leads iDirectGov's team of federal systems engineers and serves as chief architect for new product integration. Fuchs has more than 20 years of experience in the areas of technology and the federal government and is a Senior Contributor to MilsatMagazine.

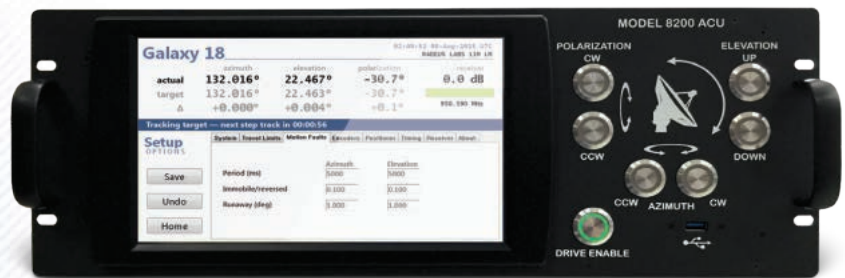




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U.S. SPACE FORCE & THE SPACE INDUSTRY TEAMING UP TO PROVIDE UNPARALLELED ACCESS TO SPACE



An Atlas V carrying the USSF-7 mission with the X-37B orbital vehicle lifts off from Space Launch Complex-41 at Cape Canaveral Air Force Station, Florida, May 17. The mission marks the 80th successful mission in a row for the National Security Space Launch program. As part of America Strong's collaborative salute, this launch was dedicated to people affected by COVID-19, healthcare workers, and first responders. Photo is courtesy of United Launch Alliance.

U.S. Space Force (USSF) partnerships with commercial space launch providers are foundational to America's National Security Space

Launch (NSSL) program which provides all aspects of flexible, secure, cost-effective and successful access to space for the gamut of payloads critical to national security.

"The United States' launch capability is the envy of the world, and U.S. Space Force Industry partnerships are a large reason why this is true," said Lt. Gen. John F. Thompson, Commander of the U.S. Space Force's Space and Missile Systems Center (SMC) and program executive officer for space.



Lt. Gen. John F. Thompson

"The NSSL program acquires and fields certified launch services to deliver National Security Space payloads to their intended orbits. The program's key priorities are: mission success, transitioning National Security Space payloads to new launch vehicles, assuring access to space for current and future space architectures, and cultivating innovative mission assurance," said Col. Robert Bongiovi, Director of SMC's Launch Enterprise.

During the last 20 years, the NSSL program has conducted 81 successful launches that has resulted in \$63 billion in U.S. space capabilities successfully placed on-orbit, making it the most successful launch program in the world. Through competitive bidding, the program has saved U.S. taxpayers \$7 billion since 2013.

"Each launch represents a significant milestone and advancement in terms of how we build, test, and deploy space capabilities in a rapid and responsive manner," said U.S. Space Force Chief of Space Operations, Gen. John "Jay" Raymond.

SMC Launch Enterprise provides flexible access to space through a range of NSSL and non-NSSL launches, from suborbital targets and experimental flights to highly reliable, medium-to-heavy space lift with multiple-mission payloads. Leading the way in fostering emerging small launch providers with multiple contract mechanisms, SMC can award launch services contracts in weeks versus months or years.

"Multi-manifest capabilities provide USSF with more flexibility by allowing it to launch several missions at once, and in multiple orbits," said Brigadier General D. Jason Cothorn, Vice Commander of SMC and program executive officer of SMC's Enterprise Corps. "This means getting more prototypes and operationally capable small satellites into orbit at reduced cost and increased speed."

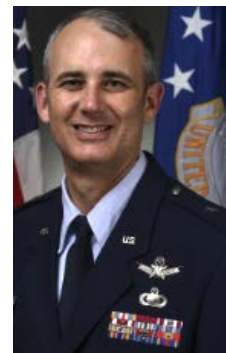
Most recently, Phase 2 space launch procurement contracts, which were awarded to United Launch Alliance LLC (ULA) and Space Exploration Technologies Corp. (SpaceX) in August 2020, leveraged commercial space launch innovation and fostered a robust competition, saving taxpayers billions of dollars. This also marks the first time in 20 years that the United States will have two independent families of launch vehicles that meet all USSF payload requirements.



Col. Robert Bongiovi



Gen. John W. "Jay" Raymond



Brig. Gen. D. Jason Cothorn



An Atlas V carrying the USSF-7 mission with the X-37B orbital vehicle lifts off from Space Launch Complex-41 at Cape Canaveral Air Force Station, Florida, May 17. The mission marks the 80th successful mission in a row for the National Security Space Launch program. As part of America Strong's collaborative salute, this launch was dedicated to people affected by COVID-19, healthcare workers, and first responders. Photo is courtesy of United Launch Alliance.

"At the same time, the Phase 2 contract with its five-year 'block buy' offers our industry partners a solid business foundation from which they can continue to innovate and expand future capabilities to support emerging national security space needs," added Gen Cothran.

"The stability inherent in the Phase 2 contracts also enhances U.S. Space Force-industry collaboration while executing our very successful mission assurance process," Col Bongiovi said. "Since NSSL missions are more complex with requirements not found in commercial launches, collaboration is essential to maintaining our perfect record of mission success and delivering space capability to the warfighter."



Dr. William B. Roper, Assistant Secretary of the Air Force

"Innovation itself is a battlefield," said Dr. William B. Roper, Assistant Secretary of the Air Force for Acquisition, Technology and Logistics. "Every new technology happens somewhere: in some school, laboratory or business; every new market entrant, somewhere; every new war-winning capability, somewhere. Given the daunting challenges we face against peer competitors, the operative question is: 'What are we doing to tip the scales?'"

"The answer is to transform the U.S. Air Force (USAF) and USSF into early-stage 'investors' that leverage private capital, accelerate commercialization using military missions and increase the number of companies that partner with the USAF and USSF," Roper noted.

He added, "Past weapons breakthroughs — such as satellites, microelectronics and the internet — were created nearly exclusively for the U.S. military at costs prohibitive to most nations, let alone individual companies.

"There are many reasons why the U.S. Air Force and Space Force are ideal innovation partners," Roper continued. "Our funding is significant, non-dilutive and patient; our payment system is finally faster and more predictable; and our mission and people, all critical to national security and prosperity. With nearly a billion dollars dedicated annually to start-ups and scale-ups, we're one of the largest potential early-stage 'investors' in the U.S. And these dollars connect to our \$160 billion-per-year military market where successful entries can be higher in risk, lower in

quantity and higher in price as they bridge towards future commercialization — the future awaits — but only if we make it each day."

The U.S. Space Force is ushering in a new era of launch with Phase 2, with new and exceptional capabilities that rely solely on U.S. domestic propulsion. With this new fleet of vehicles, SMC's Launch Enterprise continues to ensure the space domain is secure, stable, and accessible.

Contact SMC at SMC@spaceforce.mil



A Falcon 9 launch vehicle carrying GPS III SV 03 lifts off from Space Launch Complex - 40 at Cape Canaveral Air Force Station, Florida, June 30. The first-stage booster of SpaceX's Falcon 9 Launch Vehicle was successfully recovered approximately 20 minutes after liftoff by the company's autonomous drone ship. This launch marks the first NSSL mission where a launch provider has attempted to recover flight hardware. SV03 will join the current GPS constellation comprised of 31-operational spacecraft, and will be the 22nd military code-capable satellite added to the fleet. Photo is courtesy of SpaceX.

BRIG. GEN. COTHERN DISCUSSES NSSL AT THE RAND CORPORATION SPACE LAUNCH VIRTUAL PANEL



Brig. Gen. D. Jason Cothorn

Brigadier General D. Jason Cothorn, Vice Commander of Space and Missile Systems Center (SMC), was one of four panelists on September 8th for a Space Launch Virtual Panel discussion hosted by the RAND Corporation's Space Enterprise Initiative.

"The launch enterprise obviously is the bedrock of access to space and the men and women of the United States Space Force," Cothorn said. "We're responsible for launching the nation's most critical war fighting assets: the national security space satellites. These missions are our nation's eyes and ears and provide a gamut of capabilities from communications to position, navigation and timing, to our forces around the globe and ensure that we have additional war-fighting capability in an increasingly contested environment."

The nonprofit research organization's other panelists were Bonnie Triezenberg, Senior Engineer at RAND and lead author of the RAND report, "Independent Analysis of the Global Heavy Lift Launch Market,"; Yool Kim, Senior Engineer at RAND and Principal Investigator of recent research on the risks of foreign components in U.S. launch vehicles and co-author of "A Separate Space: Creating a Military Service for Space"; and Gary McLeod, Senior Policy Researcher at RAND and Principal Investigator of recent research on launch sites to support the National Security Space Launch program and lead author of "Enhancing Space Resilience Through Non-Materiel Means." The discussion was moderated by Bruce McClintock, RAND Space Enterprise Initiative lead. Ted Harshberger, RAND Vice President and Director of Project AIR FORCE, introduced the panel.

Cothorn said the U.S. Space Force is doing its part to enable and expedite a robust space launch capability for the United States through competitive contract

awards and the National Security Space Launch (NSSL) and small launch programs that support not only Department of Defense (DoD) missions, but also NASA and commercial sector missions.

This year, the U.S. Space Force (USSF) has seven NSSL launches and four smaller launch missions, which represent a significant percentage of total U.S. launches.

"Our Phase 2 contract awards manifest plans for about 34 missions through fiscal year 2027, and the space manifests, support and facilitate robust U.S. space launch capability," Cothorn said. "SMC has proactively worked to develop agile processes for accelerated and flexibly manifesting on the NSSL and small launch to meet our responsive space objectives."

In addition to the number one priority of mission success, Cothorn said the NSSL strategic objectives include maintaining a strong industrial base, global competitive advantage, and assured access to space. The Phase 2 contract awards are a premiere launch service contract, providing innovative, affordable and reliable services to the DoD and other entities.

United Launch Alliance (ULA) and SpaceX were awarded the Phase 2 contract in August: two firm-fixed-price, indefinite delivery requirements contracts. The launch service orders will start in fiscal year 2020 and run through 2024 with the first missions launching in fiscal year 2022. ULA was assigned the USSF 51 mission, launching in the second quarter of fiscal year 2022, and the USSF 106 mission, scheduled for the fourth quarter of fiscal year 2022. SpaceX was assigned the USSF 67 mission, scheduled for fourth quarter of FY2022.

"This competitive acquisition adds to a considerable savings we've seen in the NSSL program since the 2013 Phase 1 block buy award," Cothorn said. "To give you some numbers, total life cycle cost reduction since February 2013 when the program was re-baselined stands at \$22 billion. In addition, the NSSL program



Vandenberg AFB, Launch Complex #2

has returned approximately \$7 billion in procurement funds to the Department of the Air Force and the National Reconnaissance Office with the savings we've garnered over these years."

Cothern said SMC's Launch Enterprise was able to achieve these savings by creating innovative acquisition strategies, procuring launch services in economic order quantities, and fostering robust competition precipitated by the investments in new commercial launch systems that also meet national security space launch needs. Cothern noted there are several different ways for companies to become certified to compete for NSSL contracts, although the three-step option is the most frequently chosen path.

"I actually liked the way SMC did it for the Phase 2 launches," Triezenberg said. "First you do an experimental launch — launch your Tesla into space if you're Elon Musk — then you had to go out and get a commercial launch to show you were viable in the market. And then you finally did a third launch which was a government, more experimental platform. So with that body of three launches, at that point you were entered into the competition for our more expensive satellites.

"I thought that was a pretty good progression," Triezenberg added. "There are enough smaller, experimental satellites out there that are available for those kinds of launches that we can do that kind of progression, and there's always people in the commercial market who are willing to take the risk of that first flight if you're willing to give them a low-enough price."

"The Launch Enterprise has capabilities and the contracts in place to launch nearly any payload to any orbit," Cothern said. "Over the last decade we've developed the robust launch infrastructure. As we work toward the range of the future it will reduce future launch operating costs while evolving to a world-class instrumentation architecture [for] both commercial and government space launch."

Triezenberg spoke about the global heavy lift launch market and the market factors that influence companies to enter and exit the business, with government support being the most influential factor. When preparing a launch vehicle to market, government support can be important to helping firms survive economic downturns. Lack of government support also can allow foreign competitors to enter the market.

Once the market is more mature, government national security contracts can either help or hurt a company, depending on how that company is strategically placed in the market. And while a company might hope government support isn't necessary, "the evidence suggests that it is absolutely essential if a firm is going to survive in this market with even one launch failure," Triezenberg said. "Firms that don't have that support can quickly go bankrupt."

The U.S. Department of Defense is looking at various ways to achieve space domain mission assurance in the face of numerous threats to critical space assets, Kim said. In today's context of reconstitution — being able to bring new assets on line or restore

function after an attack or catastrophe — launch is one of many key elements. Many of these concepts have been demonstrated to a degree, but the DoD would need to be able to maintain ready crews, which could be a very high cost endeavor, Kim said.

"Substantial investments in infrastructure would have to be made at the ranges and there would need to be additional storage facilities, additional launch pads and the range safety process would have to be streamlined," Kim added. "This wouldn't work for on-demand launches. Developing a responsive launch program could be a costly endeavor." There isn't a widely accepted definition for responsive launches, Kim said, adding that it largely depends on the user.

"You can argue that launch providers today — heavy lift and small — are meeting the customer's needs on a timeline," Kim said. "In the context of reconstitution — responding in terms of on-demand launches and very short timelines, that has not been done other than in a demonstration environment."

McLeod discussed launch resilience, or launch infrastructure that's resilient to mishaps. Launch sites can be vulnerable to both adversary attacks and natural phenomena, such as wildfires and earthquakes along the Western Range, and lightning strikes and hurricanes along the Eastern Range. Ranges have been addressing natural hazards for decades through a variety of measures, but remain vulnerable to cybersecurity threats.

Both Cothern and McLeod agreed that the U.S. launch capacity is sufficient, although Cothern noted that there still are overflight restrictions if someone wants to launch something in a different orbit than is traditional for a particular range, citing the Argentinian SAOCOM-1B satellite on the Falcon 9 from Cape Canaveral into a Polar orbit.

Fortunately, short-notice cancellations are usually not a problem, McLeod said, particularly for national security launches. Ranges know about those 18 months in advance, so a delay of one or two weeks is not critical. Commercial launches are more dependent on launch-on-demand, however, it's still hasn't presented any major issue.

"The bottom line is, we believe industry stability and predictability increases success — our number one priority — while also reducing cost," Cothern said. "The U.S. Space Force will continue to work with any of the non-selected launch service providers that choose to continue work on their vehicle certification efforts at their expense, and we look forward to continuing to ensure that we have a robust industry to support our needs."





SATCOM TECHNOLOGY & THE CONNECTED SOLDIER

By Ulf Sandberg, Founder and Managing Director, Paradigm Communications Systems

With the advent of wireless communication and simple, easy to use, high throughput, satellite communication terminals, peacekeeping and conflict resolution has undeniably entered the 21st century. Body-worn POV (Point of View) video cameras and health capturing devices can now feed real time, vital data to Command Centers. Data can now be reliably and securely transmitted and received in extreme environments to levels that have never been reached before, opening up a new world of field personnel protection.

When communicated via satellite, this data can be used anywhere in the world and by a much wider audience. The value of data is immeasurable and the connection of devices and supply of live data is rapidly gaining importance, nowhere more so than in the conflict arena. The development of soldier-borne data devices has arisen from the need for rapidly delivered accurate and up to date situational information to give immediate oversight, as well as from the concern and value placed on the lives of those placed in harm's way. Heart rate

monitors are partnered with physiological and biometric sensors and more prevalent use of video cameras stream footage of first person POV integrated positioning sensors, allowing for critical tracking information. This ongoing development of wearable technology has seen the rise of wireless local area networks that offer autonomous network creation in order to propagate the data from the soldier out into the hands of others.

Delivering this information to those who know what to do with it has become as important as capturing it, creating a problem that has evolved alongside the development of personnel borne technology. Collecting the data isn't enough; the adoption of personnel sensors, camera feeds and local mesh radio networks don't show their full capability until the network is expanded out and beyond the local area of conflict. It's this network expansion to place the information in front of a wider, more qualified audience that makes the difference; this audience will have the capability to monitor and evaluate in an

environment that is less stressful, allowing them to think more clearly and make more effective decisions.

Using whatever wide area networks that are at hand initially appears the obvious option; the networks are ready and seemingly capable of connecting an existing local mesh network to the wider world. In built-up population centers, it would be assumed that local cellular networks would be used — after all, 4G and LTE network speeds are increasing all the time. But they bring an inherent lack of security, quality and reliability, operating as they do on the model of sharing the network with other cellular users. Consequently, the commonly witnessed fluctuations of a terrestrial network's performance and signal coverage means users are gearing toward adopting satellite communication rather than the cellular option.

Satellite communication continues to advance at the same rapid development rate as other wireless communication technologies. It has long since passed the moniker of being a complicated, expensive technology that could only be used when specialists and engineers were available, with equally specialized equipment. Satellite terminals

are now available that incorporate simplistic user interfaces. The previously complex methodology of aiming satellite terminals at satellites and maximizing operating signal has now been re-engineered to be carried out by everyday, technically literate users.

Paradigm has been spearheading this simplification of methodology with its PIM® – Paradigm Interface Module. The PIM is at the heart of modern satellite terminal operation, designed to simplify operation, reduce operating costs and provide a central unit for the integration and operation of satellite terminal hardware. The PIM controller provides a simple to use interface for the integrated modem, baseband switching, assisted pointing and setup functions of a satellite terminal and comes with a built-in visual crosshair and audio pointing device.

The PIM can support Power over Ethernet devices and provides a multitude of services to the end user — from VLAN setup and management to smart auto-selecting of AC and DC power interfaces. As well as making pointing quick and simple for any user, PIM-based terminals all have excellent, low SWaP characteristics and operational agility providing key connectivity for edge devices.



Paradigm's PIM on-board interface.



Paradigm's ultra-portable SWARM.

However, the adoption of advanced technology into the military and peacekeeping arena is often hampered by high costs that these sort of key technologies command. Satellite communication equipment has long remained in the high CAPEX area; typically expensive to buy, expensive to train on and expensive to operate. This has now started to change, initially by integrating the PIM to reduce the complexity of satellite terminals and then by offering fewer parts to assemble, tool free setups and dramatically increased portability. In addition, these advancements have been in conjunction with service upgrades and developments from the satellite operators themselves.

Previously, satellite operators wouldn't allow the connection of a satellite terminal onto their networks without first having worked with the terminal user to balance the satellite terminal's operational RF output power.

Too little power and the signal isn't strong enough to deliver a high quality connection, and the user's service suffers. Too much power, and the satellite operator's equipment and that of other customers suffer; signals are saturated by the uncalibrated transmit signal, and the user sees their service suffer once more with a loss of quality and

performance. Balance the signal power and the result is a happy satellite network, and a happy terminal user.

The advancement of equipment has now reached a level where the balancing, or calibration process, is automated. Satellite terminal users are now seeing regular connection speeds, committed information rates and overall higher quality of service than previously experienced. Partner this with a satellite terminal manufacturer such as Paradigm, who has studied the process of terminal pointing to the extent that their own terminals now include simpler, easier to follow procedures and something that was once only in the realm of highly trained experts has been brought to the masses.

Terminal pointing can now be performed by almost anyone using nothing but the PIM's LED cross-hair target and an audio tone, rated alongside home internet connections for simplicity of use. Developments haven't been restricted to ease of use though. Satellite terminals are now being classified by two other popular categories: easy to transport and simple to setup. Technological advancement can often mean taking time to observe and justify modifications. Reducing a satellite terminal to the size and weight that can be easily transported



by a single user sees a reduction in performance. Correct that reduction with leading edge flat panel technology and more efficient transmission components and pricing increases. Simplify the operation and training costs and the price reduces.

The result is a continual exercise of balance, but one where products that are adopting these advances are starting to see increased business opportunities. The goal has been to remove training costs entirely, and produce a fully automated system with no moving parts that covers operational requirements for most applications.

The market has seen select companies, such as Paradigm, step ahead in satellite terminal development, producing terminals such as the SWARM® designed for rapid transport and setup and multiple network capability, and the MANTA® for zero-interaction “just add power” operation. Satellite terminals such as these are ideal for environments where the advancement of technology is finally meeting operational requirements.

The ongoing adoption of advanced technology into the Military and Peacekeeping environment now includes this type of innovative development from the satellite communications world. Auto-generating, self-healing mesh radio networks are now relaying biometric, physiometric and geolocation sensor data, incorporating it with multiple high definition live video connections and relaying it over wider reaching satellite communication networks.

The types of satellite terminals used in operations are carefully selected by the operation planners. They’ve witnessed first-hand the options available and plan accordingly. These options range from ultra-lightweight advanced flat panel terminals, like the SWARM, packaged in military grade backpacks that deliver a rapid setup time and simple operation on the pause to vehicle mounted self-pointing terminals, like the MANTA, that can offer continued connectivity, while both stationary and on the move, and maintain a covert-level of design. The simplicity of operation of these terminals means that the personnel on the ground

do not need to be concerned that these wide area network connections may not be possible.

The personnel can be, and are, multi-skilled. They no longer require a particular satellite communication speciality, thus expanding the personnel options available to the operations teams. Now operations can deliver high definition, on scene first person perspectives from Beyond-Line-Of-Sight (BLOS) environments to recipients located on the other side of the world with extremely low latency.

Operation in mines and underground structures is now possible, relaying health and on scene medical information in two-way communication. Medical personnel from specialist health centres are able to connect directly to support teams requiring emergency response and deliver real-time advice on treatments to improve the long-term health options of those in need. In conclusion, the advanced development of simple to use satellite communication equipment continues to improve Military and Peacekeeping operations all around the world.

paracomm.co.uk

Author Ulf Sandberg has more than 35 years of experience in the global satellite and telecommunications world. He started Paradigm in 1996, where he has spent the past 24 years as the company's Managing Director.





IS CLOUD SECURITY SAFE FOR SATELLITE MISSIONS?

By Simon Halpern, Chief Operating Officer, Kubos Corporation

The evolution of the world is dictated by the speed of evolution of technology. Governments, industries and organizations develop new technologies to strategically grow and drive value and profit.

Cloud computing is one of the fundamental technologies that has been, and continues to be, a large factor in the evolution of our modern world, and it is defined as the delivery of computing services — including servers, storage, databases, networking, software, analytics, and intelligence — over the Internet (“the cloud”).

While many organizations have migrated away from physical computing infrastructure to the cloud, the idea of migrating to a cloud-based system is still met with apprehension from some organizations — especially organizations in highly-regulated industries such as aerospace and defense.

The reason for apprehension is the perception that cloud-based systems are inherently less secure than physical, on-premise systems. However, many organizations that rely on secure data for their existence are proving this notion is outdated and incorrect. Image for post Image for post Cloud Computing by ProSymbols from the Noun Project

Cloud computing services, such as Amazon Web Services (AWS) and Microsoft Azure, are being used to overhaul and modernize the IT operations of U.S. defense and intelligence agencies. In 2013, a \$600

million secure cloud was developed by Amazon Web Services for the Central Intelligence Agency (CIA), and it now services all 17 intelligence agencies.

An example of a contract granted by the DoD to a cloud computing service provider is the recent \$10 billion JEDI contract given to Microsoft in order to modernize its infrastructure so DoD personnel can access and manipulate data, regardless of location. The DoD also plans to use this cloud technology to support ongoing innovations in artificial intelligence.

The Pentagon may be one of the most secure areas on the planet, both in a physical and cyber sense, and now has invested \$10 billion to move from an antiquated technological infrastructure to a nimble, equally or potentially more secure, cloud-based one.

A recent *New York Times* article stated, “Federal officials have said government won’t fully maximize the benefits of the cloud until it focuses more on the opportunities it can provide than worrying about cybersecurity, and indeed many agencies with particularly sensitive information have begun to overcome these fears.”

The National Security Agency (NSA) is also moving all its mission data to a classified cloud environment. Commercial cloud services are also used by blue chip corporations such as Apple (Apple iCloud), GE

Oil & Gas, Samsung, and Netflix to scale operations, to become more nimble, to drive costs down, and to realize greater growth and profitability — all while maintaining extremely high levels of cybersecurity. Netflix may not have been the streaming superpower as we know it, had the company not overhauled their technology and migrated fully to the cloud.

These organizations, and the industries they are in, have continued to evolve with greater computing power through cloud technology. Our mission ground control technology, Major Tom, works in tandem with AWS and Azure to offer the same potential to organizations who use satellites in space to conduct missions.

As previously mentioned, AWS is the same cloud technology used by the CIA, and through AWS or Azure, Major Tom is compliant with the rigorous cybersecurity measures dictated by the National Institute of Standards and Technology (NIST) 800-53 Revision 4 framework. Furthermore, Major Tom will be eligible for FedRAMP compliance — a federal government-focused compliance with even more stringent guidelines than those given by NIST.

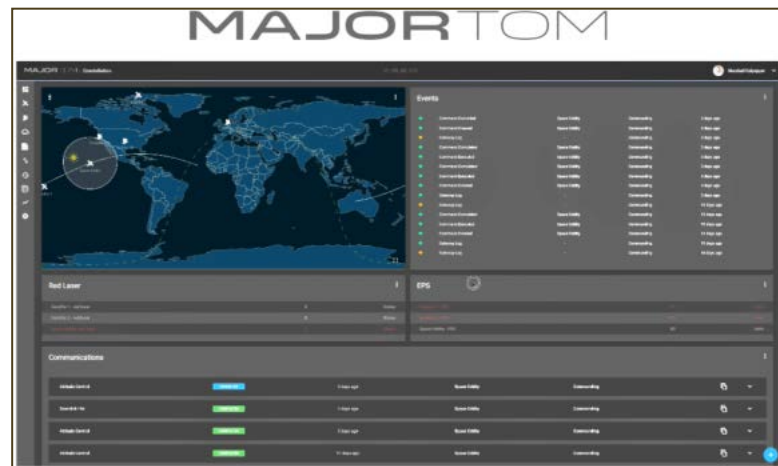
Major Tom's cybersecurity strength not only lies in its ability to protect data from hackers and other bad actors, but also in the fact that it guarantees an enterprise's data is stored and hosted on a geographically isolated US, EU, Asia, South America or other national server and not elsewhere (i.e. not hosted in a country in which the primary user country does not have amicable relations with). Also, it ensures that only specified entities can access the enterprise's data in the cloud. This type of compliance is known as Government Cloud compliance (GovCloud).

Kubos, as a founding member of the Orbital Security Alliance, understands the paramount importance of cybersecurity. It is also apparent that the U.S. military and intelligence agencies also understand that cybersecurity in space is of utmost importance to any organization or country that is developing a footprint in space through space-related missions. In fact, the United States Air Force, alongside the Defense Digital Service, held a Space Security Challenge at DefCon 2020 (one of the world's longest running and largest hacking conventions): Hack-a-Sat.

This is a challenge that brought the world's best security researchers and hackers from all organizations and agencies to solve cybersecurity challenges on space systems, and ultimately attempt to hack a satellite. The idea is this: the Pentagon is investing heavily in space-based programs, with a focus on building out satellite networks, and if the Pentagon increases its satellite presence in space, it must also deeply understand cybersecurity to protect those satellites. Back to Kubos security standards: Major Tom enforces server-side HTTPS for all user interaction as well as all ground station and scripting interfaces.

HTTPS is a secure web protocol that protects data from unauthorized viewing, tampering, or misuse. This protocol makes sure

users are safe from advanced spoofing, injection, and man-in-the-middle attacks. For Major Tom Enterprise, encryption certificates — certificates containing keys used to encrypt electronic messages, files, documents, or data transmissions — are renewed yearly through Amazon and/or Microsoft as the root certificate issuer. For Major Tom On-Premise ("air-gap") licenses, the certificate issuer and renewal process is fully configurable by the customer. All certificates use SHA-256 with RSA Encryption. In short, Kubos upholds the highest levels of security measures.

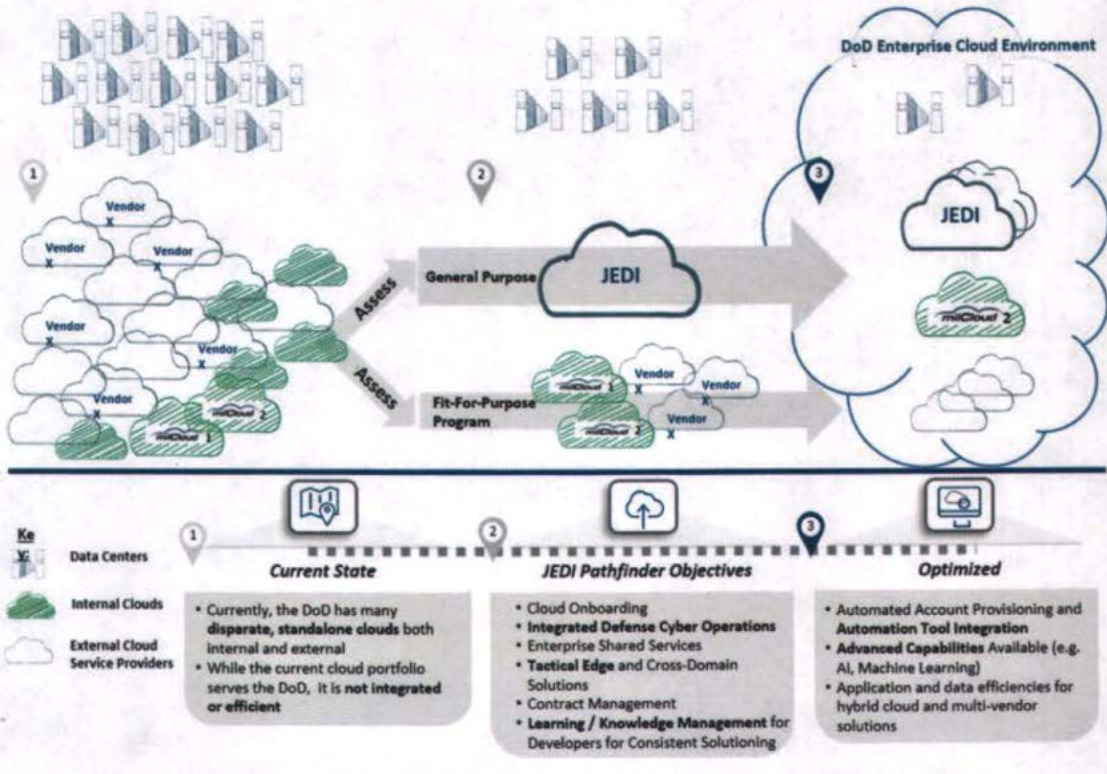


Kubernetes was developed and designed by engineers at Google as an open source container orchestration platform that automates manual processes involved in deploying, managing, and scaling containerized applications. Through Kubernetes, Major Tom can enforce fine-grained access control through both Ingress and Firewall configuration.

According to RedHat Inc., one of the first companies to work with Google on Kubernetes, "Kubernetes clusters can span hosts across on-premise, public, private, or hybrid clouds. For this reason, Kubernetes is an ideal platform for hosting cloud-native applications that require rapid scaling, like real-time data streaming."

Our Major Tom software is cloud-native, meaning it is purpose built for the cloud model, and it provides a consistent development and automated management experience across all cloud infrastructures (private, public, and hybrid). In short, an enterprise can build applications that run on any cloud without modification. Image for post Image for post Credit: Deloitte

Moving back to the question of security of cloud technology, Consider this: a recent Deloitte survey of more than 500 C-suite executives, business unit leaders, managers, and programmers reveals that security and data protection is actually the top driver for initiating migration to the cloud. This may seem counterintuitive granted that many are under the notion that the cloud is not secure. However, cybersecurity attacks are rising in sophistication, and a shortage of skills means that many companies struggle to manage security in-house.



DoD Pathfinder to Hybrid Cloud Environments and Multiple Vendors

* JEDI — Joint Enterprise Defense Infrastructure

Executives and leaders are turning to third-party cloud and managed security services, with cloud providers offering complex and sophisticated cyber solutions that help significantly to mitigate security concerns. Another fact to point out from the Deloitte survey is that 91 percent of respondents said that their companies store data primarily on the cloud. Even more, 57 percent of the surveyed organizations’ businesses operate fully on the cloud — meaning that all of their applications and data are on it. Industry executives and leaders evidently see cloud as the key to modernizing their companies’ data-based technologies, and organizations are generally optimistic about data modernization even if some organizations don’t currently have formalized plans for data modernization or cloud migration.

Cloud technology is modernizing data platforms across all industries, and it is helping us push forward the boundaries of analysis, experimentation, and achievement. It has been the cornerstone of the CIA’s and Department of Defense’s largest and most significant IT redesigns, all the while still holding a perception by the general IT public of lacking security.

Leaps and bounds have been made by cloud technology service providers to ensure strength in cybersecurity, and regulatory mandates have been set in place to ensure organizations engage only with service providers who are in compliance with the required cybersecurity standards. Highly regulated industries, such as the space industry that Kubos operates in, tend to be laggards in adopting frontier-expanding technologies.

According to a Deloitte survey, 19 percent of respondents from the technology, media, and telecommunications (TMT) industry have either not begun data modernization or have only begun planning for data modernization. However, corporate executives, government leaders, defense leaders, and developers understand that cloud technology is a positive force in driving our global computing power forward, and in realizing immense technological advances.

The JEDI contract between the DoD and Microsoft is the most significant recent evidence of understanding. Kubos is bringing cloud technology to space. Our company is making it more cost

effective for operators and spacecraft builders to build and operate their satellite constellation.

Furthermore, Kubos is following the strict guidelines of regulatory bodies as well as the research of leading cybersecurity experts to make sure the data related to missions are secure, and to make sure the user experience of our software is robust, intuitive, and cohesive. As the cost basis of space-related missions comes down, more missions — and more impactful missions — become viable, the industry grows, and our world advances.

There’s a reason why the DoD, the CIA, and major blue-chip corporations have adopted cloud technology early as a core part of their operations:

*“Victorious warriors win first and then go to war, while defeated warriors go to war first and then seek to win” ☐
Sun Tzu, The Art of War*

Author Simon Halpern is the Chief Operating Officer at Kubos Corporation.



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NOTIONAL SATELLITE ARCHITECTURES OF MILITARY (GEO-EARTH) VERSUS SPACE EXPLORATION (GEO-MARS)

By Ronald H. Freeman, PhD, Vice-Chair of Space Operations and Support Technical Committee, American Institute of Aeronautics and Astronautics (AIAA)

Generally, the worldwide use of space systems is broken down into three user communities: Commercial, Civil and Military. Each of these communities share common needs, interests and uses of space systems and services.

The commercial space user community is primarily interested in broadcast communications, point-to-point communications, position and navigation services, and imagery. The civil space community is composed of non-military and non-intelligence government agencies that use space.

In the U.S., the largest civil organizations engaged in space are NASA and NOAA. NASA is charged with exploring space, doing science missions focusing on the earth and our solar system, and developing technology for use in space. NOAA is responsible for weather monitoring and forecasting, which relies heavily on space-based assets.

The military space community is composed of the armed forces and the intelligence agencies that use space as a medium from which to gather information or as an environment in which to execute operations.

Intelligence users are interested in employing satellites to monitor activities in denied areas.

Military users are interested in satellites to help with navigation, weather forecasting, and worldwide communication, in addition to intelligence gathering to support specific military engagements.

For space architectures with multiple satellites, the launch segment plays an important role in mission risk reduction and constellation replenishment and maintenance strategies.

The ground segment often includes a choice of whether to use data downlink gateway systems in space (Tracking and Data Relay Satellite System) or on the earth (e.g., the Deep Space Network, or Air Force Satellite Control Network for continual execution of Telemetry, Tracking, and Commanding (TT&C) operations).

Also of consideration is where data processing will take place and how mission data will be stored and distributed. Assuming 50 pictures of 500 MB of high resolution imagery every day for 10 years, the space system architect has 91 terabytes of information to store (the equivalent of the U.S. Library of Congress' entire contents).[1]

Space system design often starts with needs and a concept.

Engineers perform trade studies by setting baselines and making minor changes to seek improvement in performance, cost, schedule, and risk. The culture of the industry that grew through an Apollo race to the moon and large defense contracts in the 1970s and 1980s was slow to adapt to better design systems.

Experience has shown that the design vector presents the least stable element in the trade space. Modular designs included as many variables as practical in a “constants” vector rather than “hardwiring” the values into code. These could be design variables were assumed to have weak impact, or variables that could conceivably change in the future but were not expected to impact the design. [2]

Orbit types and parameters are generally selected to provide the greatest benefit for the least cost, based on the purpose and capabilities of the satellite. The four most common orbit types used by the military are Geosynchronous Earth Orbit, Highly Elliptical Orbit, Medium Earth Orbit, and Low Earth Orbit (Figure 1). Generally speaking, space system architectures are classified by the mission performed.

The launch of constellations of small satellites providing high-band width data to terrestrial users was cost-prohibitive in the past, particularly with COMSATCOM. Satellites were optimized for a specific

orbit based on function. This meant that a dedicated launch platform was required. Because launch costs were high and a functional satellite could only be built above a certain weight, a self-reinforcing incentive cycle developed. Miniaturization of satellite components and increased understanding of the space environment now allow functional platforms to be built that are significantly lighter than those of the past. [3]

The National Oceanic and Atmospheric Administration (NOAA) Satellite Observing System Architecture Study developed a satellite plan with broad trade-space regarding instruments, platforms, launch policy, and orbits likely available in a 2028 timeframe. Nearly 100 prototype constellations were developed based on different configurations of instruments and orbits. The forward-looking, quantitative, cost-benefit analysis was not intended to deliver a particular point solution with definitive satellite constellation, instrument vendor, or data service provider. Rather, it identified options to inform budget and program decisions. [4]

A new generation of cooperative spacecraft designed specifically for on-orbit servicing (OOS) missions could upgrade its hardware every few years—a need identified by the commercial, civil, and military satellite sectors. This would end the current paradigm of relying on monolithic-purposed satellites with decades-old hardware and technology, then having to launch replacements to modernize them.

	Communication	Positioning and Navigation	Weather	Remote Sensing
Objectives	Broadcast coverage; point-to-point, global user communications; data & voice relay between orbit spacecraft and ground controllers	POS/NAV missions for near global coverage with triangulation strategies. Line of sight from ground receivers.	--GEO satellites for near latitudes. --Polar orbiting satellites for high latitude global areas	Many sensors to collect data could produce visual spectrum images, IR spectrum images, elevation measurement, atmospheric gas measurement, ocean states
Providers	DirecTV, Iridium, TDRSS	GPS (US), Glonass (USSR)	SES (Luxembourg) Viasat (USA)	Landsat (NASA/USDS), GOES (NOAA)
Constellation class	1+ GEO or 10+ LEO/MEO satellites	1+ MEO satellites		GEO satellites for persistent coverage in a fixed small area with a strong signal; LEO satellites for infrequent coverage of a large area with a weaker signal

FIGURE 1.

OOS refers to on-orbit activities conducted by a space vehicle that performs up-close inspection of, or results in intentional and beneficial changes to, another resident space object (RSO). These activities include non-contact support, orbit modification (relocation) and maintenance, refueling and commodities replenishment, upgrade, repair, assembly, and debris mitigation. [5]

Public-private partnerships have incentivized the OOS market with commercially driven services and technologies. Recent start-ups rooted in Silicon Valley business tactics have increasingly launched smaller and more affordable satellites for their constellations. With the sharp increase in spacecraft, the shift towards an always-connected, Internet-of-Things (IoT) mindset in space is paramount. In practice, satellites receive and direct data from millions of small, uncoordinated sensors from remote areas with low data rates. Flat antennas allow for IoT backhauling on any platform, including high throughput satellites or other fixed satellite services, which would allow for IoT to have a more significant presence.

With OOS support, Defense Advanced Research Projects Agency (DARPA) has pioneered the concept of using robots in space. Active Debris Removal (ADR) technology demonstrated the best way to capture the estimated 40,000 pieces of space debris orbiting Earth. In a public-partnership with Space Infrastructure Services (SIS), sophisticated satellite servicing was commercialized, including that of refueling.

Moreover, SES Networks operated more than 50 geosynchronous satellites and 12 mid-Earth orbit satellites. Governments and commercial interests appear to be pivoting GEO-based capabilities to low earth orbit. In comparison to reduced station-keeping propellant, geostationary orbits afford mission planners a fixed sub-satellite point with the advantage for broader end-to-end mission. For example, mission designs indicate nearly continuous coverage. Still, GEO constellations fail to provide access to the planet's polar regions, a driving requirement for some mission. [6]

NASA's efforts to explore space have also been the driving factor for OOS development. Commercial resupply missions to ISS indicate a consistent need to perform rendezvous and proximity operations (RPO). If these missions are successful, the space industry will likely see a rapid growth of OOS capabilities resulting in reduced operating cost, including servicer use in satellite insurance contracts to mitigate or repair failures in lieu of replacing spacecraft.

The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) is an industry-led initiative with initial seed funding provided by the DARPA to leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and operations, OOS- and RPO-standards [7]. Large government satellite programs, take 10-15 years from an initial satellite program concept to the first satellite reaching orbit depending on system complexity and other programmatic factors.

NOAA's Global Navigation Satellite System Radio Occultation (GNSS-RO) and space weather capabilities require replenishment much earlier. Three satellites are simultaneously required on-Geo-orbit with two active (East and West) and a third as a spare (typically, centrally

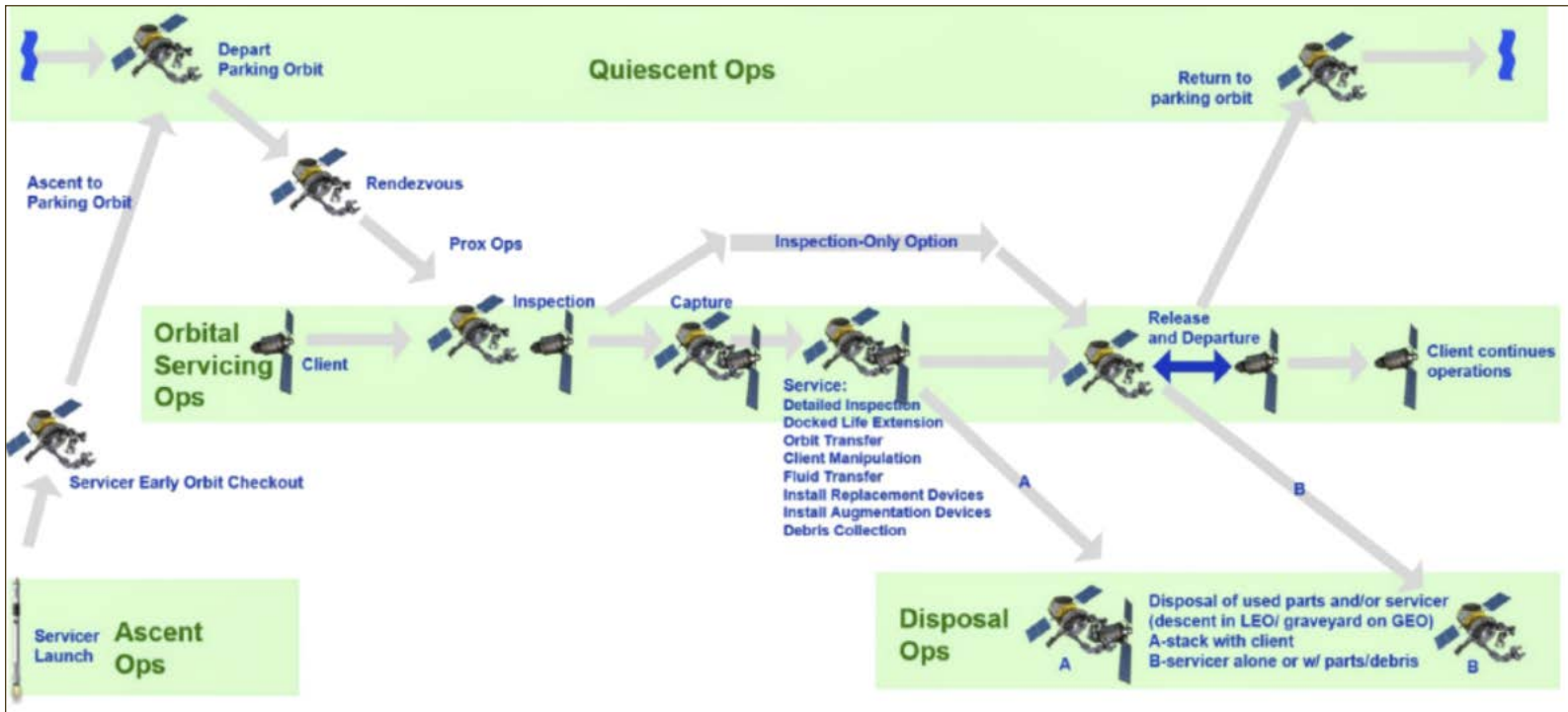


Figure 2. On-Orbit Servicing (OOS) Mission Functional Diagram.

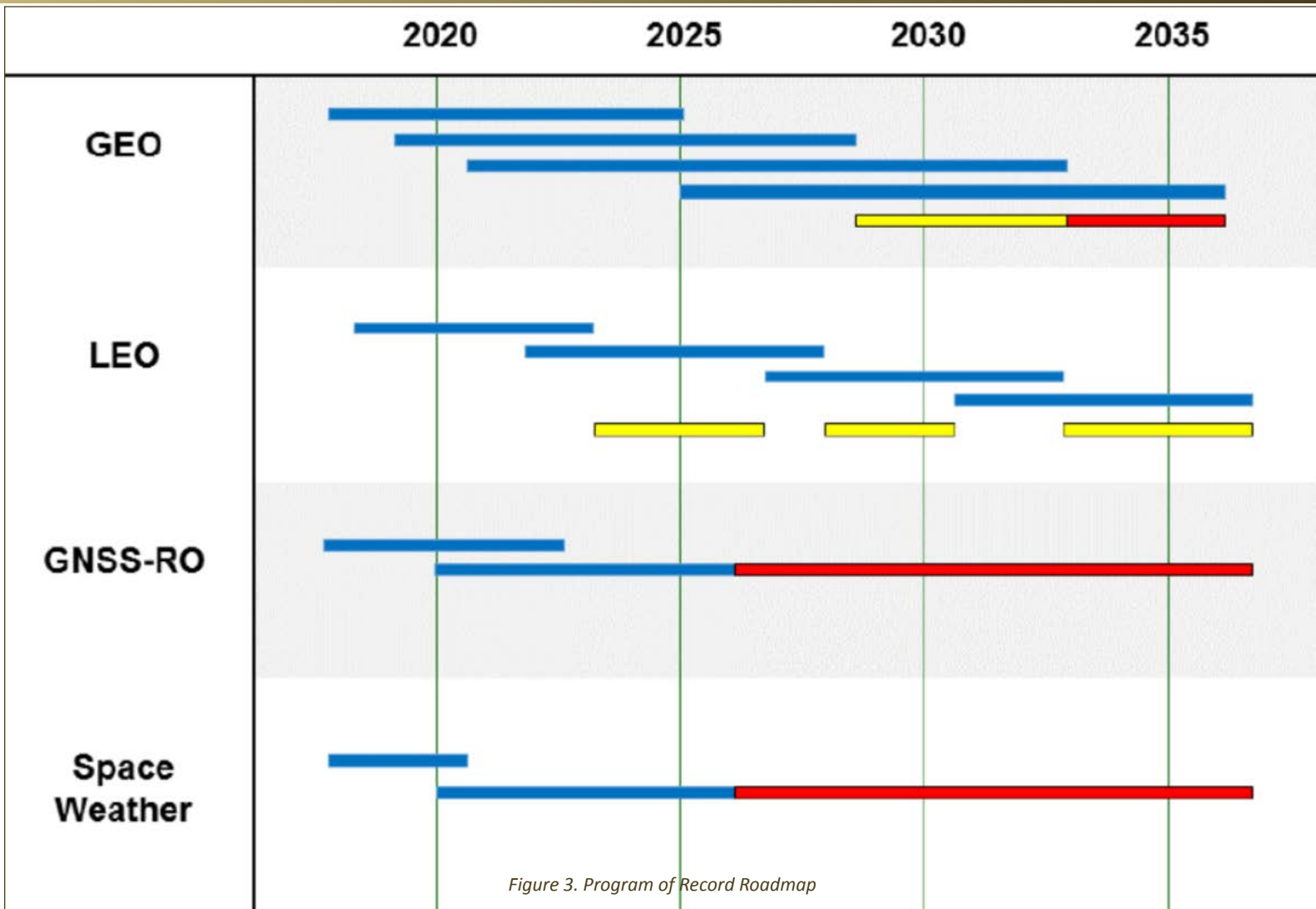


Figure 3. Program of Record Roadmap

Figure 3 above shows satellites GOES -15, GOES-17, and GOES-T, the anticipated flyout of GOES-17, replenishment capabilities availability for launch (yellow bar), and the loss of capability (early 2030s) after the GOES-T flyout (red bar). Blue lines indicate expected lifetime of launched or planned satellites or capabilities. Yellow bars indicate time periods when availability falls below the current policy. And, red bars indicate loss of capability. [8]

Smallsats are an emerging class of spacecraft that incorporates recent software and hardware improvements. When compared to traditional satellites, smallsats typically have shorter development cycles, smaller development teams, and consequently, lower cost, both for the development and for the launch of the satellites. CubeSats have the additional benefit of a standardized form-factor and containerization, enabling mass production and easier launch vehicle integration, which can further lower cost.

simultaneous deployment in large numbers. Demand and subsequent investment in on-orbit servicing, assembly, and manufacturing (OSAM) is influenced by developments in both upstream and downstream fields (e.g., communications, Earth Observation (EO), space exploration, data analytics, private launch market, etc.) [9]

GEO-Earth (Military) Notional Satellite Architecture Space is a naturally hazardous environment and is increasingly congested, contested, and competitive. Natural threats to satellites include solar activity, radiation belts, and natural orbital debris. Man-made threats can be both unintentional (e.g., satellite debris or electromagnetic interference) or intentional (e.g., jamming, lasing, cyberspace attacks, and anti-satellite weapons).

Nations are also developing, and in some cases demonstrating, disruptive and destructive space capabilities. Consequently, space situational awareness (SSA) functions as a defense strategy dependent on integrating space surveillance, collection, and processing; environmental monitoring; status of US and cooperative satellite systems; understanding of US and multinational space readiness; and analysis of the space domain. Since space assets provide combatant commanders (CCDRs) with near-worldwide coverage and access to

otherwise denied areas, the advantages using space for operational purposes include freedom of action, overflight, and global perspective and responsiveness.

Missile warning mission uses a mix of space-based and terrestrial sensors. Satellite communications (SATCOM) systems facilitate beyond line of sight connectivity. Terrestrial and space environmental monitoring support to joint operations gives the joint force commander (JFC) awareness of the operational environment (OE). Functions common to joint CCDR operations at all levels of warfare consist of seven basic groups: command and control (C2), intelligence, fires, movement and maneuver, protection, sustainment, and information. SSA assists C2 by characterizing the space environment, including the ground and link segment. SSA provides insight into an adversary's employment of space systems [10].

A limited war strategy is to protect and defend US and Allied interests in space. Secondary objectives include (1) the ability to negate especially critical adversary space systems that place joint and coalition forces at extreme risk during terrestrial operations; (2) the ability to reconstitute or build resiliency into space architecture; and (3) to continue supporting the joint terrestrial force with war-winning, space-based enabling capabilities such as the Global Positioning System, missile warning, and satellite communications [11].

Space Development Agency (SDA) recognizes the need to establish an "intellectual pipeline" to access ideas from across the community to inform the future of the National Defense Space Architecture (NDSA). SDA specifically seeks novel architecture concepts, systems, technologies, and capabilities that:

1. Enable leap-ahead improvements for future tranches of currently planned NDSA capability layers

2. Enable new capability layers to address other emerging or evolving warfighters needs.

The year-old Space Development Agency (SDA) emphasizes speed in pursuing innovative space capabilities [12]. A proliferated Low Earth Orbit (LEO) constellation of satellites and sensors connect to the military's tactical legacy datalinks and weapons systems to deter against advanced threats. In particular, beyond the line-of-sight targeting capabilities and enabling the detection, tracking and fire control of advanced missile threats would be a part of the system. The architecture is focused on delivering the initial capabilities of beyond the line-of-sight targeting for time-sensitive targets, both ground and maritime.

The SDA's effort to create and sustain resilient, affordable and lethal space-based capabilities as part of the NDSA for the military also provides the space-based backbone for the services' Joint all-domain command and control, or JADC2. Specifically, the SDA is looking to

field advancements across the transport, battle management, tracking, custody, deterrence, navigation and support layers of the NDSA. The agency also is addressing capability gaps in the military's space solutions, including providing space situational awareness in extended space to cis-lunar space between the Earth and the moon's orbit.

The backbone transport layer of hundreds of satellites in low-earth orbit (LEO) will all be optically connected to form a mesh network in space. SDA will fly about 20 transport satellites to form the network and enable communications to legacy tactical datalinks. The data transport layer will talk directly via existing tactical datalinks (e.g., Link 16), down to weapons systems that are already fielded and already have such capability (e.g., Army's TITAN ground system).

Three sensing layers will feed data to the transport layer:

(1) a tracking layer made up of overhead persistent infrared (OPIR) sensors to detect and track adversarial advanced missiles

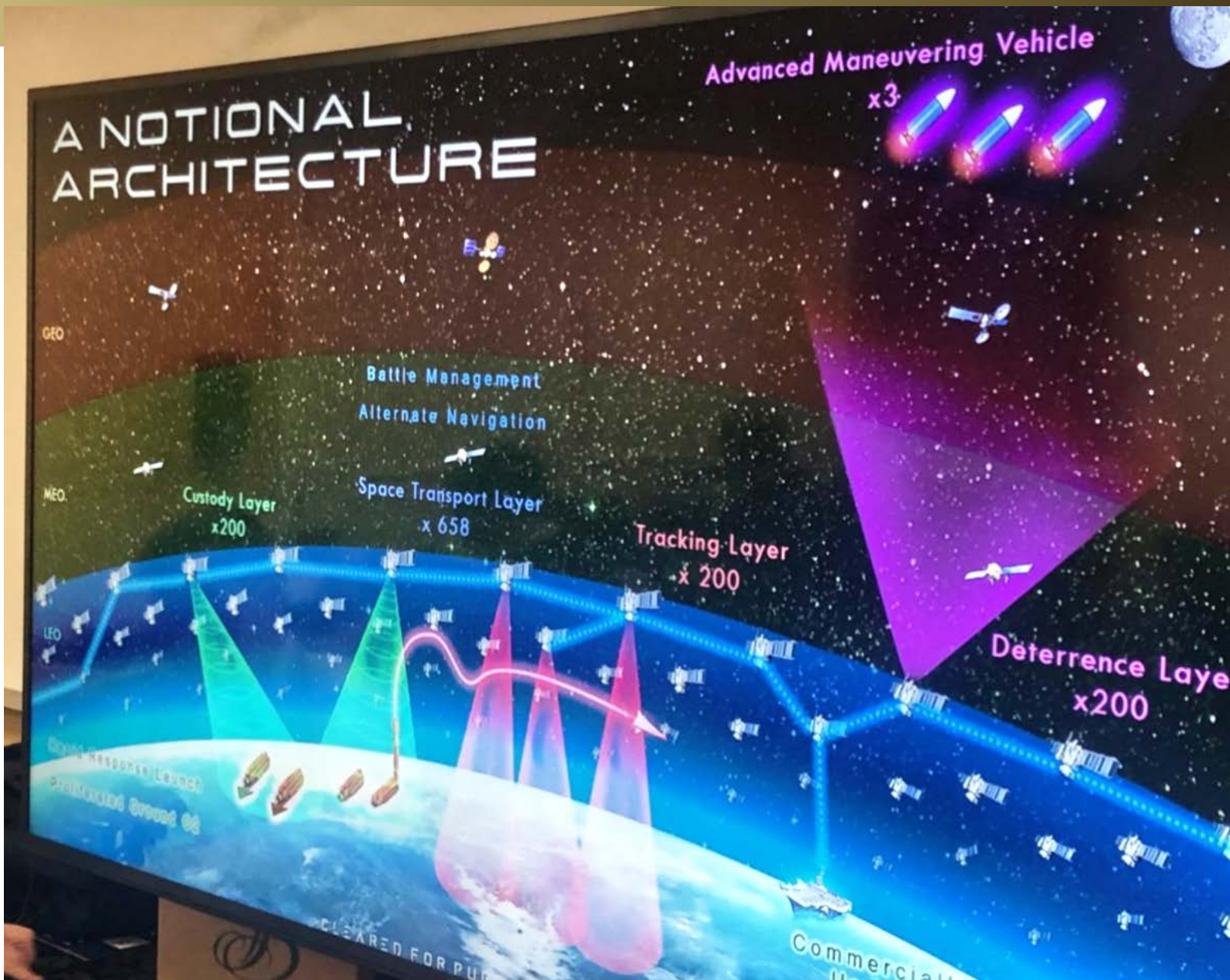
(2) a custody layer that would allow military users to send target location information in real time directly to weapons systems

(3) a deterrence layer for space situational awareness. The sensing satellites will detect the missile; send the track to the transport layer where that data could be fused with other data and then sent down to the ground to the actual weapon systems that would engage the threat.

The SDA would fly eight wide field-of-view sensors in Tranche Zero to demonstrate the traceability used for hypersonic glide vehicle detection over the entire globe, as well as for passing the data either directly to the ground or to the transport satellites.

For the custody layer, the SDA will rely on mission partners—the Army, Air Force and other agencies—to build out ISR satellites to provide the beyond-line-of-sight targeting capability. In Tranche Zero, the SDA is working to show that it can move data to the ground from the mission partners, send data from the partners directly back up to the SDA transport satellites, and then send that data over the mesh network to other areas of interest.

"For example, if the Army had one of their TITAN ground stations and they have that located in Germany, they could download the data to that system in Germany, send it back up to transport, where then it would be used by transport satellites to go down to an F-35 in the INDOPACOM Theater via Link 16," Derek Tournear, Director of the SDA clarifies. "That's one example that we're going to demonstrate in Tranche Zero."



Space Defense Agency "Notional" Space Architecture Reaches For The Moon

For the third sensing layer, the SDA is conducting studies on how to best design a deterrence solution that provides detection and tracking beyond geosynchronous orbit out to cis-lunar space. And that sensing would feed data back into the transport layer. Operating in that environment has historically been ignored due to a lower priority over items that are in LEO or geosynchronous.

A battle management layer of the NDSA architecture would tie all the layers together and would be where onboard processing, algorithms for autonomous operations and any automatic target recognition algorithms would run.

"In order to do those missions, essentially the autonomous detection and tracking, and targeting of time-sensitive targets and missiles, there is a lot of processing that needs to be done," Tournear clarifies. "That processing will reside ultimately on board the sensing satellites as well as the transport satellites. That's our battle management layer."

Moreover, the position, navigation and timing (PNT) data of the NDSA transport layer offers an additional PNT signal to individual users that are tied into the associated communications network. To help enable the military's JADC2 operations, the NDSA platform would connect to all of the services' ground and air networks tied into JADC2 [13].

The US military has come to rely on space-enabled capabilities ranging from communications to the Global Positioning System (GPS), in order to achieve battlefield effectiveness. Many systems and units cannot function without space-enabled capabilities, and this has created a vulnerability that near-peer adversaries of the US and its allies are unlikely to ignore. In other words, space is becoming "increasingly, congested, contested, and competitive." [14]

The US is a space-dependent nation when it comes to military operations. Air Force Space Command (AFSPC) focuses on deterrence both in space and terrestrially and exercises both offensive and defensive capabilities. In negating adversary counter-space systems, all

parties are likely augment space-based capabilities with local terrestrial equivalents like high-altitude long-endurance drones, pseudolites for position, navigation, and timing (PNT), terrestrial radios, fiber lines, or commercial intelligence, surveillance, and reconnaissance (ISR) capabilities. Additionally, these conceptual systems defend vital orbital regimes or points in space, such as Molynia orbits, certain sections of the geosynchronous belt, cis-lunar and lunar orbits, and earth-moon LaGrange points. LEO orbits are too numerous and inclinations too varied to actively defend with "cruisers," except for perhaps some sun-synchronous orbits.

Within the rest of LEO, defenses on-board the high-value asset seems best suited to that orbital regime. Their cheap and in-depth maneuverability applies best in escorting high valued systems to new mission-dependent sites [15]. The development of agile, responsive next-generation space architecture will counter near-peer efforts to contest or deny US space-based systems. The notional architecture SDA developed is predicated on the availability of a ubiquitous data and communications transport layer and assumes the use of small, mass-produced satellites.

The architecture includes seven layers:

Space transport layer: A low-latency data and communications proliferated "mesh" network to provide 24/7 global communications.

Tracking layer: To provide early warnings of advanced missile threats

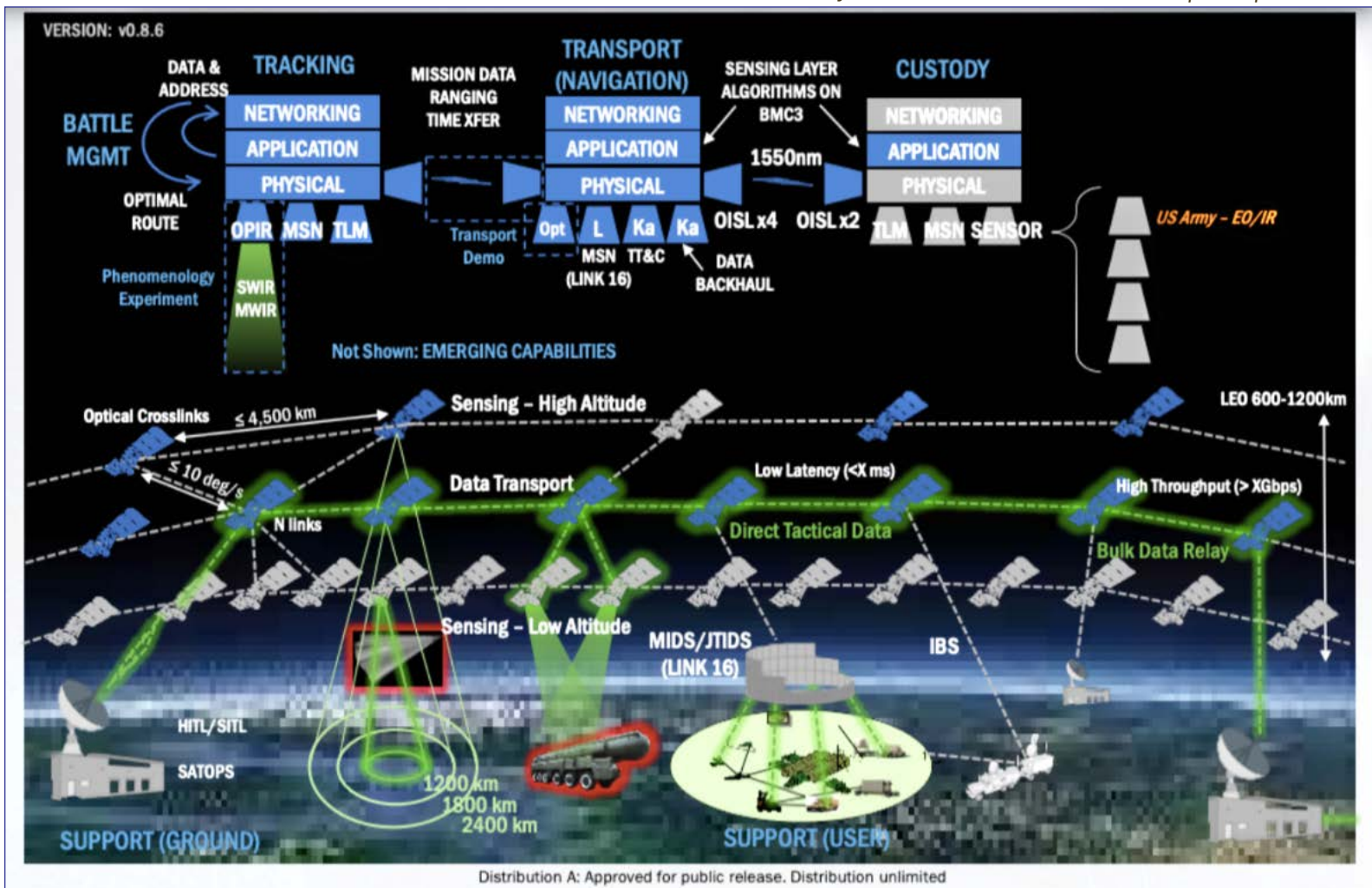
Custody layer: To keep watch over time-critical targets

Deterrence layer: To provide space situational awareness of, and access, to the cislunar spac

Navigation layer: To create an alternative positioning, navigation and timing system for GPS-denied environments

Battle management layer: An artificial intelligence system to help deliver space sensor-derived data directly to tactical users

Support layer: Mass-producible ground command and control systems, user terminals and and rapid-response



Distribution A: Approved for public release. Distribution unlimited

Figure 5.

The Army has roughly 100 tactical ground stations, 13 operational ground stations and a few other dissemination vehicles to inform battlefield commanders. Tactical Intelligence Targeting Access Node (TITAN) aims to consolidate much of those capabilities to better provide "deep sensing" information from intelligence, surveillance and reconnaissance sensors from all domains.

The scalable system is an expeditionary intelligence ground station, leveraging space and high altitude, aerial and terrestrial layer sensors to provide targetable data to fires networks. It also provides multi-discipline intelligence support to targeting, situational awareness, and understanding for mission command. Since the sensors will compile massive amounts of data, TITAN will need to rely on artificial intelligence and machine learning to sift through it [16].

SDA head *Fred Kennedy* presented this notional satellite architecture at Space Symposium on April 9, 2019. He wants to launch the first satellites for the transport layer in 2022.

SDA plans to roll out a "tracking layer" of about 200 satellites meant to provide global coverage of advanced missile threats using infrared

satellites that use radar, electro-optical/infrared cameras and signals intelligence to sense and monitor objects on Earth—potential targets of interest, and how they may be moving or changing. The SDA's notional architecture proposes a four part deterrence layer.

The first part, located in LEO, would be made up of outward facing space situational awareness sensors capable of providing data on deep space objects located immediately beyond geosynchronous orbit [17]. Additionally, development of a number of "advanced maneuvering vehicles" (i.e., X-37 successor or another spacecraft) promises to move between the Earth and the moon more quickly and efficiently than an adversary could, and deliver effects, potentially even weapons [18].

Case Study

Set in the year 2026, this wargame, named in honor of retired General *Bernard A. Schriever*, explored critical space and cyberspace issues in depth and investigated the military utility of emerging space systems and cyberspace capabilities.

NASA's Optical Plan Forward: User Terminals for LEO and the Moon

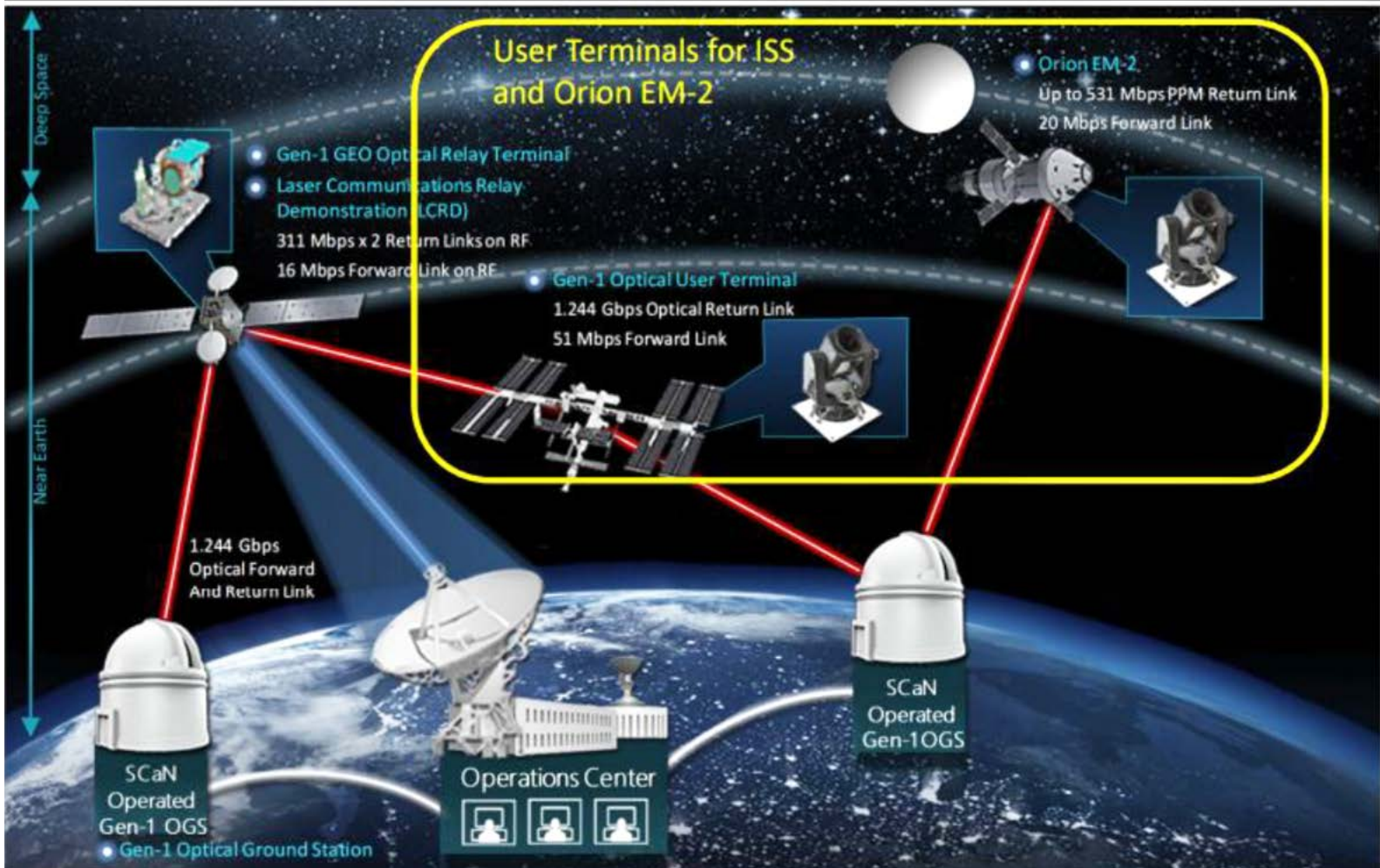


Figure 6.

The objectives of the wargame included:

Explore and assess the resilience of a future architecture in a contested, degraded, and operationally limited environment

Identify processes; concepts of operations (CONOPS); and opportunities for tactics, techniques, and procedures (TTPs) development within a future architecture to improve defense and mutual support of all elements of National Security Space

Examine how future anti-access and area denial (A2/AD) force structures will affect requirements for Air Force space operations and services.

This wargame highlighted the resilience of a future space architecture that incorporated characteristics of increased flexibility, maneuverability, and situational awareness, as well as the crucial role that U.S. allies and the commercial sector play in space and cyberspace capabilities. Key take-aways from the game include the importance of multi-domain awareness and integration, the warfighting value of our allies, and the operational contributions of commercial space.

As the wargame unfolded, a regional crisis quickly escalated, partly because of the interconnectedness of a multi-domain fight involving a capable adversary. The wargame participants emphasized the challenges in containing horizontal escalation once space control capabilities are employed to achieve limited national objectives. Approximately 175 military and civilian experts from government agencies around the U.S, as well as Australia, Canada, and the United Kingdom participated in the wargame [19].

GEO-Moon-Mars (Deep Space Exploration) Notional Satellite Architecture

GEO space-ground signals cross mostly cloud-free zones, wherein atmospheric turbulence causes sudden drops of signal lasting for many milliseconds. Unlike the growing space domain of GEO-Earth (Military) Notional Satellite Architecture with the extremely narrow divergence of the beams challenging Pointing, Acquisition, and Tracking (PAT) across the vast distances of space, Deep Space Network (DSN) has developed a new hybrid RF and optical antenna, capable of doing both RF and optical spacecraft passes with the same aperture [20].

Space Communications and Navigation (SCaN) serves as the Program Office for all of NASA's space communications activities. SCaN manages and directs the ground-based facilities and services provided by the Deep Space Network (DSN), Near Earth Network (NEN) and Space Network (SN), and the SN's space segment, the Tracking and Data Relay Satellites (TDRS). NASA's Plan of 2017 was for an Orion Exploration Mission-2 near the lunar orbit with data transfer directly to SCaN.

The optical plan also included two user terminals for inter-satellite communications and data transfer to ground stations and ISS. However, data rates per deep space missions will increase by about one order of magnitude per decade for the next 50 years. The next two orders of magnitude are predicted to come from the introduction of deep space optical communications [21].

Improvement will result from Ka-band communication (about 100 Mb/s) for the LRO mission and laser communications (up to 622 Mbps) from Lunar Atmosphere and Dust Environment Explorer (LADEE) mission [22]. Commercial companies have a significant interest in free-space optical communication (FSOC) with world governments having invested in the initial infrastructure while retiring the technical risks on integrated photonics technology. Integrated photonics drove the costs of FSOC to well below those of RF systems in order for commercial networks of "fiber-in-the-sky" to realize fiber optic transmitter and receiver subsystem for the generation, coding, amplification and reception of light. [23].

Designed to demonstrate high-bandwidth, bidirectional optical communications relay services between GEO and Earth, Laser Communications Relay Demonstration (LCRD, 2020) mission consists of two independent laser communication terminals, connected via a new electronic switch to provide high-speed frame switching and routing between the two optical space terminals (OSTs) while also serving as the interface to the host spacecraft.

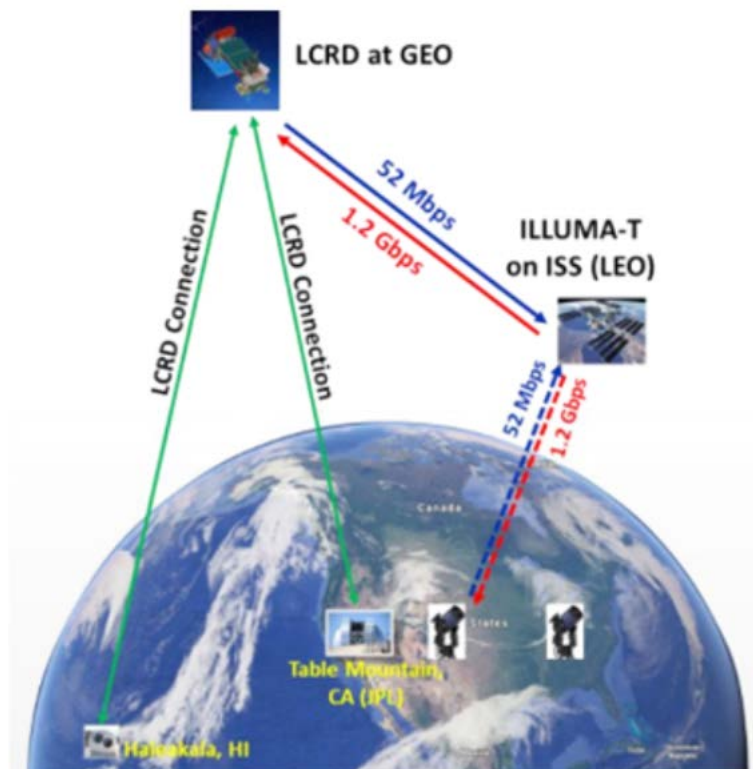


Figure 7. ILLUMA-T operational characteristics. Primary mission requirement is to communicate through LCRD.

"space relay" communications link from a spacecraft LEO up through LCRD in GEO and then down to the ground. Specifically, NASA is developing a new optical terminal to demonstrate on the international space station (ISS) in 2020 that is interoperable with LCRD for future space users in LEO or higher.

This next-generation terminal will leverage recent developments in integrated photonics, which should lower SWaP and cost of the flight modem by an order of magnitude relative to RF systems. The new terminal may even replace the current LCRD terminal design for GEO if radiation requirements can be met [24]. (See Figure 7 on the previous article page.)

Designed to provide the significant capability required for human deep-space exploration, NASA's Space Launch System (SLS) also provides a unique opportunity for lower cost deep-space science in the form of small-satellite secondary payloads. This opportunity will be leveraged beginning with the rocket's first flight; a launch of the vehicle's Block 1 configuration, capable of delivering at least 26 metric tons (t) to trans-lunar injection (TLI), which will see the Orion crew vehicle travel around the moon and return to Earth. On that flight, SLS will also deploy thirteen 6U CubeSat-class payloads to multiple destinations in deep space.

The EM-1 smallsat, one of four payload missions, is a Near Earth Asteroid Scout mission (MSFC) equipped with a solar sail to rendezvous with an asteroid and gather detailed imagery data.

Second, Lunar Flashlight mission (JPL) will look for ice deposits and identify locations of extractable resource lunar sites. BioSentinel mission (Ames Research Center), a yeast radiation biosensor, will measure effects of space radiation on DNA.

And, Lunar IceCube mission (Morehead State University) will search for water in ice, liquid and vapor forms as well as other lunar volatiles, using a compact infrared spectrometer.

LunIR mission (Lockheed Martin) performed lunar flyby using a Mid-Wave Infrared (MWIR) sensor to collect spectroscopy and thermography data. From deep space beyond the moon, the CubeSat Mission to Study Solar Particles (CuSP) mission (Southwest Research Institute) will support space weather research by determining proton radiation levels during Solar Energetic Particle (SEP) events [25].

Beyond GEO, some cislunar objects reside in low lunar orbit (LLO), a region within 100 km of the Moon's surface. Since there is very little atmosphere on the Moon, objects can orbit at very low altitudes. The Moon has an uneven gravitational field. Consequently, satellites in LLO may have to make frequent station keeping adjustments to stay in orbit. The gravitational environment surrounding the Moon substantially limits operational capabilities for satellites and future space stations.

The Lagrange points are locations in space where the gravitational forces from two large bodies, like the Earth and the Moon, balance each other. Lagrange points are important because spacecraft or satellites can stay in a stable orbit without having to expend much fuel. The Earth-Moon Lagrange Points are strategically important because they are favorable locations to anchor commercial or military satellites and space stations. Or, the Lagrange points could serve as an appealing place to build trade and logistics terminals where crew or cargo arriving on spacecraft from Earth could be transferred to lunar landing vehicles. Alternatively, crew and cargo could launch from the lunar surface, dock with the station, and take a new vessel back to Earth.

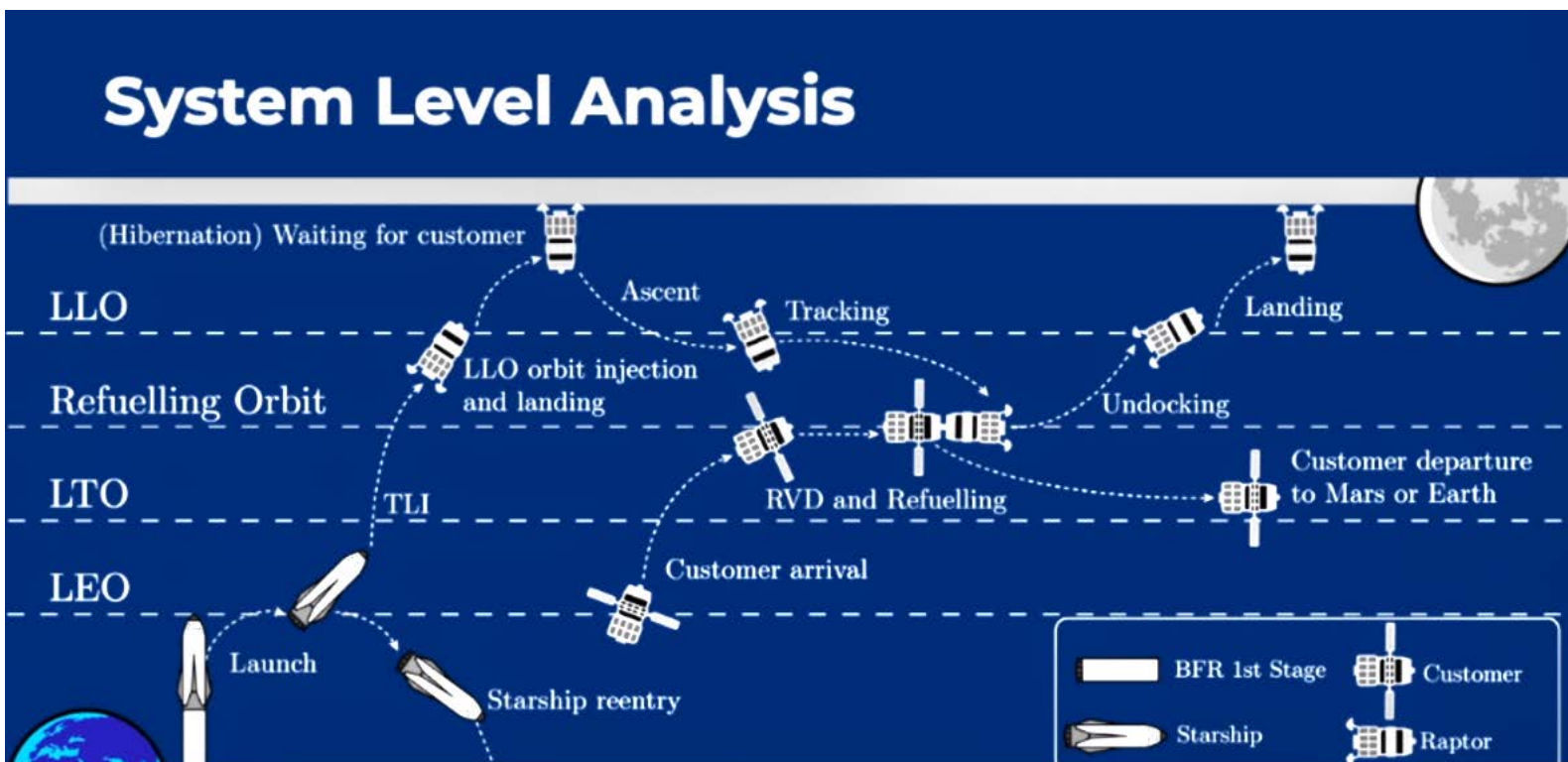


Figure 8.

Earth-Moon L_2 libration point satellites will provide navigation capability for the far side of the Moon. Grebow (2006) created architectures for continuous lunar south pole coverage by two satellites located in quasi-periodic orbits around the Earth-Moon L_1 and L_2 . Romagnoli and Circi (2010) investigated Lissajous orbits around the Earth-Moon collinear libration points to realize a Lunar Global Positioning System (LGPS), The attractive L_2 , L_4 , and L_5 locations for future positioning, navigation, and timing (PNT), SSA, and communications platforms will enable satellites to “see” behind the Moon, a part of cislunar space not visible from Earth.

The U.S. Space Force (USSF), in partnership with private vendors, plans development of a three-dimensional interface for lunaspatial intelligence (LUNINT) collection and a PNT constellation for cislunar space [26]. Lunar development serves as a critical proving ground for deeper exploration into the solar system [27]. NASA developed LunaNet architecture based on interconnected network nodes to create a terrestrial-like internet in space.

With the increase in human and robotic exploration at the Moon, space-based users, surface assets or lunar orbiters can use LunaNet's network nodes as access points, analogous in functionality to terrestrial Wi-Fi routers and cellular towers. LunaNet architecture is based on nodes capable of providing a combination of the following three standard services, illustrated in Figure 9 to the right.

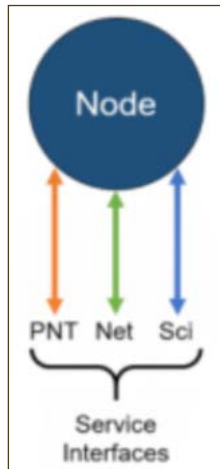


Figure 9. A LunaNet Node with its Standard Service Interfaces.

1. **Networking Services (Net):** Data transfer services capable of moving addressable and routable data units between nodes in a single link or over a multi-node, end-to-end path.

2. **Position, Navigation, and Timing Services (PNT):** Services for position and velocity determination, and time synchronization and dissemination. This includes search and rescue location services.

3. **Science Utilization Services (Sci):** Services providing situational alerts and science measurements for human and asset safety and protection. Science instrument data will also allow for further research, increasing return on investment overall.

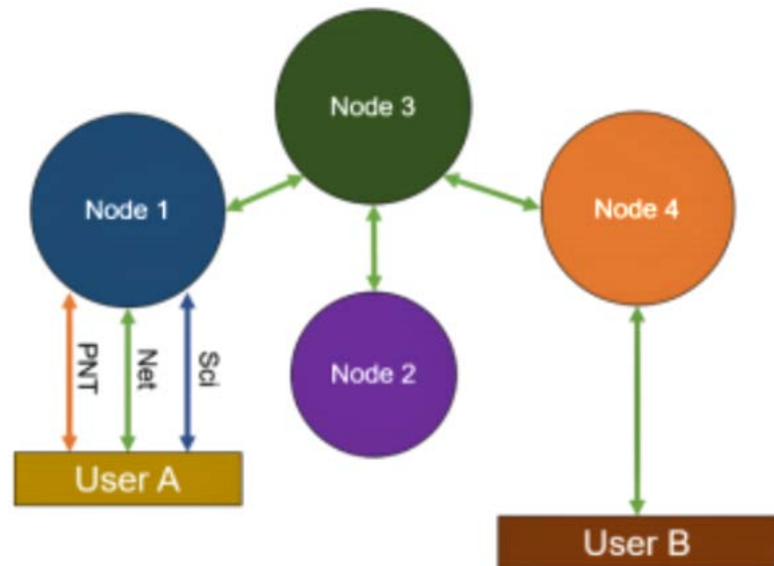


Figure 10. User A receives networking, PNT, and Science Services through Node 1 and is able to Communicate with User B through LunaNet.

LunaNet nodes may be connected together to provide the end-to-end path. In the example illustrated in the Figure 10 above.

User A, through Node 1 as its LunaNet access point, communicates with User B over multiple nodes providing networking services. Node 1 is simultaneously providing PNT and Science Utilization Services. The functions of an individual node within the larger architecture would influence amount of capabilities for each service type required for that node. The combination of nodes could be a heterogeneous set of assets:

1. Commercial, government, international, etc.
2. Spacecraft in any orbit or surface elements
3. Dedicated spacecraft or hosted payloads.

The architecture will aggregate links, funneling different sources of data to come together to one point to get combined into a single stream of data, as appropriate, to more efficiently use available links and to minimize the total number of links required [28].

NASA's long-term plans for deep-space exploration focus on returning astronauts to cislunar space and constructing the Lunar Orbital Platform-Gateway in preparation for exploration of Mars; opportunities for small satellite payloads will likely be a part of these deep-space exploration plans.

NASA has selected SpaceX of Hawthorne, California, as the first U.S. commercial provider under the Gateway Logistics Services contract to deliver cargo, experiments and other supplies to the agency's Gateway in lunar orbit.

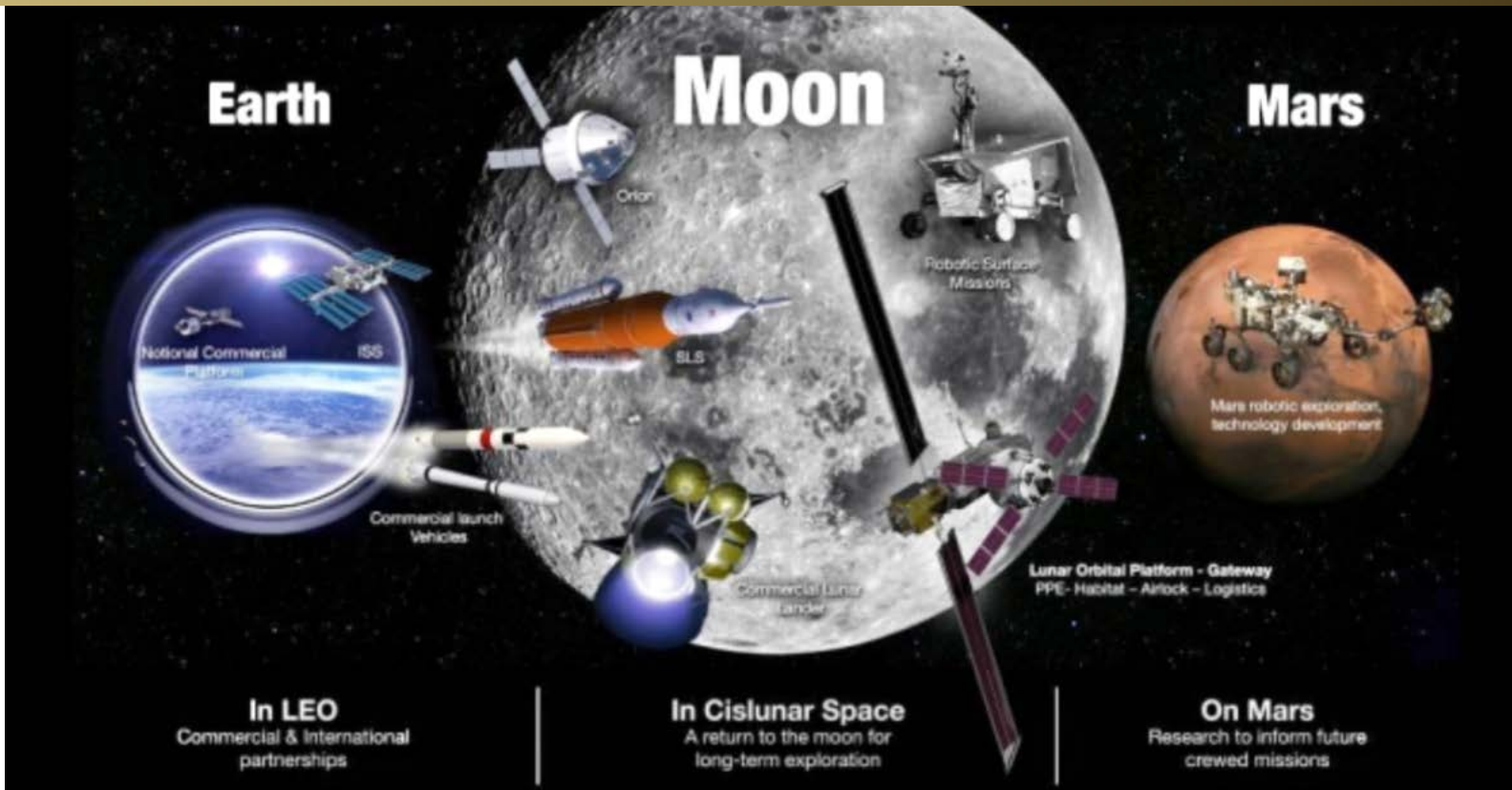


Figure 11.

NASA will have multiple supply missions in which the cargo spacecraft will stay at the Gateway for six to 12 months at a time. These firm-fixed price, indefinite delivery/indefinite quantity contracts for logistics services guarantee two missions per logistics services provider with a maximum total value of \$7 billion across all contracts as additional missions are needed.

As defined by the Exploration Systems Architecture Study (ESAS), the lunar architecture is a combination of the lunar "mission mode," the assignment of functionality to flight elements, and the definition of the activities to be performed on the lunar surface. The trade space for the lunar "mission mode," or approach to performing the crewed lunar missions, was limited to the cislunar space and Earth-orbital staging locations, the lunar surface activities duration and location, and the lunar abort/return strategies.

The mission mode analysis was built around a matrix of lunar- and Earth-staging nodes. Lunar-staging locations initially considered included the Earth-Moon L1 libration point, Low Lunar Orbit (LLO), and the lunar surface. Earth-orbital staging locations considered included due-east Low Earth Orbits (LEOs), higher-inclination International Space Station (ISS) orbits, and raised apogee High Earth Orbits (HEOs). Cases that lack staging nodes (*i.e.*, "direct" missions) in space and at Earth were also considered [29].

As defined by the Exploration Systems Architecture Study (ESAS), the lunar architecture is a combination of the lunar "mission mode," the assignment of functionality to flight elements, and the definition of the

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Case Study

Imagine you're in a spacecraft heading from the Earth to the moon. At what point do you stop depending on the network of Earth- and space-based sensors that tell you what's nearby, and start depending on a separate network that offers situational awareness near and on the moon? If you want to collect signals intelligence from systems emitting near the moon, what orbit do you need to be in, and how do you ensure the data can traverse a much farther distance than information in closer orbits? Those considerations are among the questions Space Force's intelligence officers are asking.

Rhea Space Activity and Australia-based Saber Astronautics, co-founders of LUNINT, will create a three-dimensional dashboard that shows the coordinates of noteworthy objects in cislunar orbit, furthering the practice of space domain awareness.

Saber aims to introduce LUNINT into the Space Force's virtual-reality "Space Cockpit" software that was developed by the 460th Space Wing at Buckley Air Force Base, Colo, as well as the commercial Predictive Ground Station Interface software.

Tools such as virtual reality enable space professionals to envision battlespace within which their satellites operate. They can turn and look at where other satellites are relative to them and learn what the other satellite is doing, why it is so near, and how I should respond in face of such a real experience.

The intuitive feel for battlespace has previously been lacking on a text computer screen. Cislunar propagators are algorithms that help and predict a spacecraft's orbital location and utilize decades of archived lunar images to map the moon's surface. Additionally, the LUNINT program will indicate optimum satellite constellation architecture to monitor cislunar spacecraft and recommend how LUNINT capabilities will fit into current US intelligence practices.

As humans return to the moon, it may require its own sort of GPS enterprise, communications, remote sensing, and more that the Earth already uses. The USSF will want to track all of that activity as it expands, ideally on a daily basis to keep tabs on where satellites, debris, and other objects are going. Space users and travelers need to establish norms of behavior to keep the amount of space debris down in new orbits, so there's less to worry about for space domain awareness [31].

The increased dependency on ground-based navigation support for an Earth-directed domain, renders a need for Earth outward-looking domain toward deep space exploration. The current baseline system for deep space navigation utilizes Earth-based radiometric tracking, requiring long-duration observations to perform orbit determination and generate a state update.

The Multi-spacecraft Autonomous Positioning System (MAPS) takes advantage of the growing inters- spacecraft communication network and infrastructure to enable network-based space navigation. A

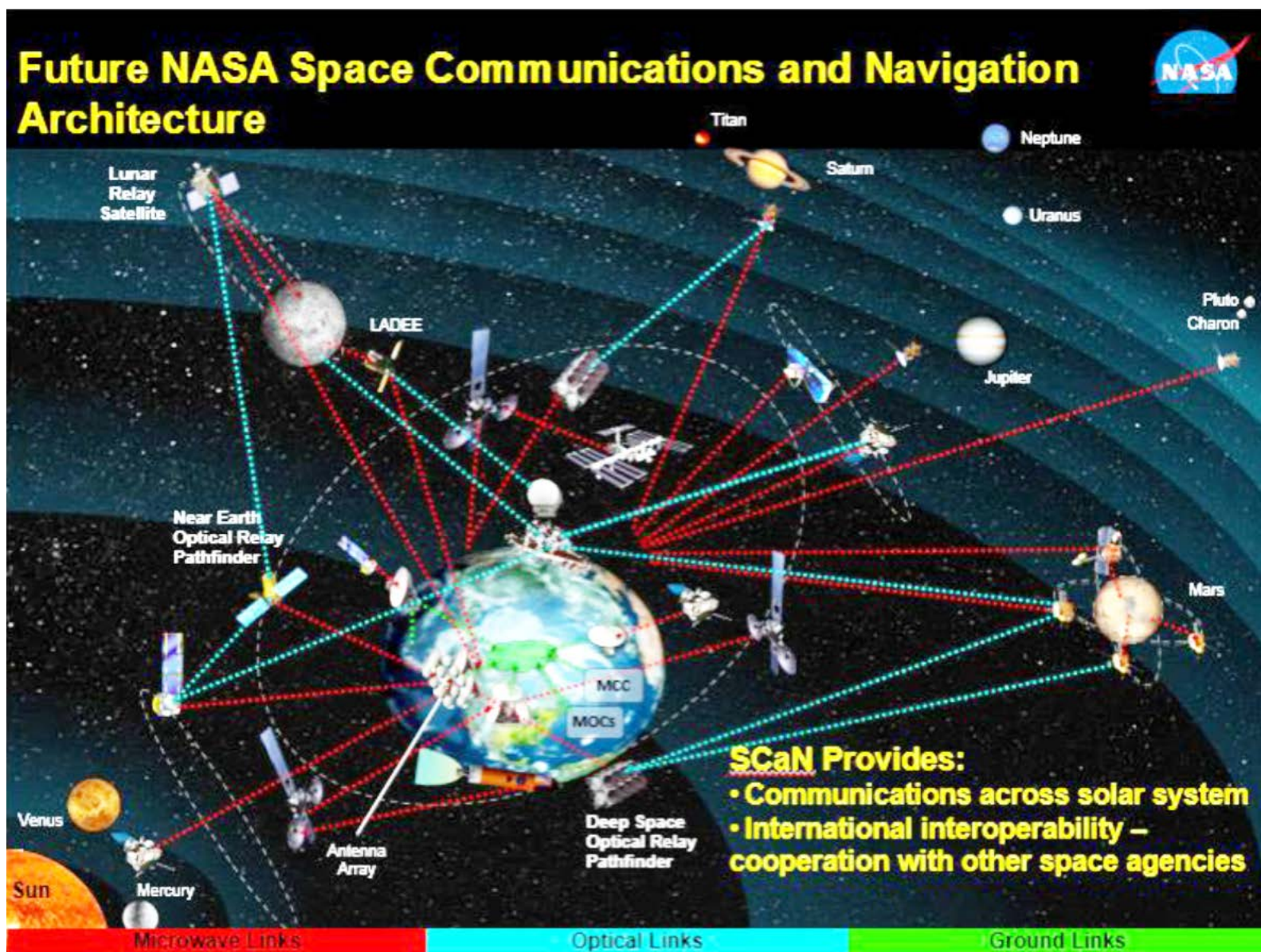


Figure 12.

notional concept of operations shows the use of the Mars Reconnaissance Orbiter and Mars Odyssey spacecraft as relays for surface assets. The growth of this communications architecture is continued through MAVEN, and future potential commercial Mars telecom orbiters. This growing network provides an initial Mars local capability for inter-spacecraft communication and navigation [32].

Many space communications and exploration strategies relate to sending robotic and human missions to destinations beyond Low Earth Orbit (LEO), including cis-lunar space, Near-Earth Asteroids (NEAs), the Moon, and Mars and its moons. NASA's Space Communications and Navigation (SCaN) program office provides communication and tracking services to space missions during launch, in-orbit testing, and operation phases. Currently, SCaN's space networking relay satellites mainly provide services to users below GEO, at Near Earth Orbit (NEO), below LEO, and in deep space.

The potential exists for using a space-based relay satellite, located in the vicinity of various solar system destinations, to provide communication space links to missions both below and above its orbit. Such relays can meet the needs of human exploration missions for maximum connectivity to Earth locations and for reduced latency. Relay satellites in Earth through cis-Lunar orbits are normally located in stable orbits requiring low fuel consumption. Relay satellites for Mars orbit are normally selected based on the mission requirement and projected fuel consumption. Relay satellites have extreme commonalities of functions between them, differing only in the redundancy and frequencies used.

The mission design methodology developed by the Collaborative Modeling for Parametric Assessment of Space Systems (COMPASS) team¹³ was used to produce the satellite relay design and to perform various design trades [33]. The report includes a detailed design of the spacecraft, a description of each sub-system and its properties, a mission feasibility determination based on the design effort, a list of possible launch vehicles, the total mass and power requirement during the various phases, and a final cost estimate for the entire mission, including non-recurring engineering costs.

As human space exploration pushes back toward the moon and onward to Mars, the architectures for extended operations are continuing to mature and move towards implementation. As part of these missions, including human landers and ascent vehicles, an increased infrastructure will need to be deployed to support long duration scenarios. One aspect of this is the ability to communicate and navigate across the lunar surface. To enable this, a Lunar-wide communication network will be deployed, sizing up with the amount of bandwidth required for operations. This network can also be used for navigation as well [34].

The Martian communication network, along with deep space network support, provides an initial architecture for simulation and analysis of MAPS, providing a notional deep space implementation. This scenario is used for initial trade studies to determine capability assessments and sensitivity analysis.

This architecture also serves as the mission scenario capturing the ideal initial deep space implementation of MAPS [35]. The fastest path to flight is to take advantage of the maturing cubesat community, with continuing expansions out into deep space, being demonstrated through the Secondary Payloads on the SLS Artemis I flight.

This approach has also already been successfully implemented and operated for Martian missions. Recently, NASA/JPL landed InSight on the surface of Mars. This mission included two companion spacecraft MarCO-A and MarCO-B, whose primary mission was two-fold: demonstrate the capability for cubesats to operate in deep space, and provide a communication relay for high-rate data collection during the lander's descent operations. [36]

The MarCO (Mars Cube One) spacecraft launched with the InSight mission from Vandenberg AFB on May 5, 2018. These spacecraft, the first interplanetary CubeSats, serve as technology demonstrators, supporting the InSight Mars lander. During InSight's entry, descent, and landing sequence, the MarCO spacecraft will flyby Mars, collecting transmitted data from the lander, and relaying it back to the Deep Space Network (DSN) on Earth.

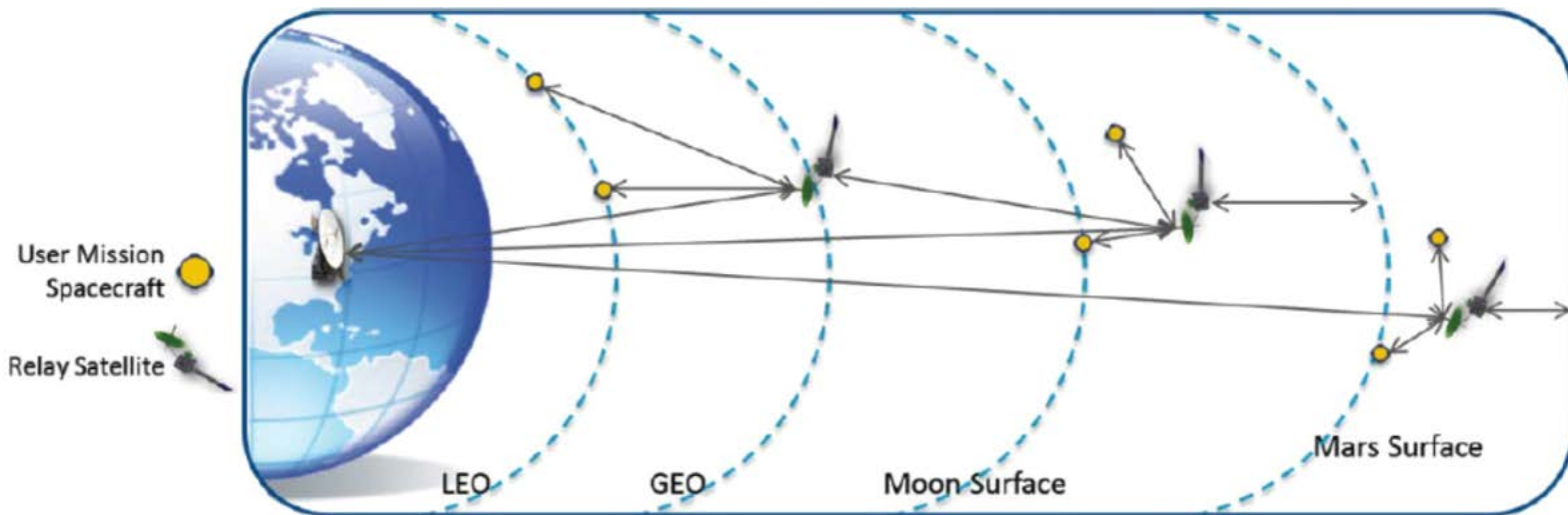


Figure 13. MAPS concept of operations: Spaced-based relay communication infrastructure concept

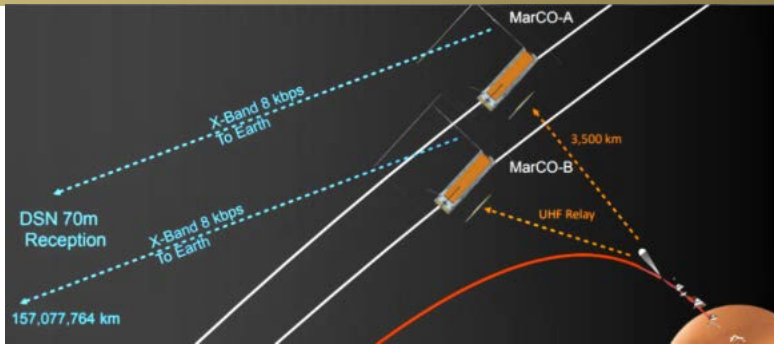


Figure 14.

This marked the first time cubesats had been launched on an interplanetary voyage, the first time three vehicles would be flying to Mars in loose proximity, and the first time secondary spacecraft have been used as a “carry-your-own-relay” concept for critical operations (InSight EDL) [37]. A low-Earth orbit (LEO) demonstration mission concept was developed and analyzed for MAPS.

This mission scenario focused on capturing the in-flight accuracy of the spacecraft clocks as well as in-flight packet transmission, and state estimation among a limited number of assets. To support this mission, both software and hardware simulation tools were developed. The simulation architecture allowed for analysis of link budgets and estimated

performance as a function of individual asset orbits and simulated errors (such as external perturbations and timing uncertainty) [38].

As the orbiting and surface elements build up in the vicinity of the Mars landing site, traditional methods that require pairing one dedicated ground station with one spacecraft to generate tracking measurements becomes impractical. This is due to a large number of flight assets in the same vicinity. Moreover, the Earth-based tracking approach is limited by the speed of light. As a spacecraft travels further from Earth, the communication lag time due to the finite speed of light increases.

Deep Space Network (DSN), a shared resource for many deep space spacecraft, operates navigation of all spacecraft to Mars using the large antennas from NASA ground stations on Earth. Therefore, the tracking time to perform precision orbit determination (OD) for four or more Mars orbiting navigation satellites would be challenging, if not impossible.

Human Mars explorations require substantial buildup of orbiting and surface infrastructures on Mars. In addition to communication coverage, location awareness is essential to supporting various human and robotic activities on the Mars surface and on orbit. This could include localizing discoveries and returning to sites, construction/assembly of structures and habitats, entry/descent/landing, approach/rendezvous/docking,

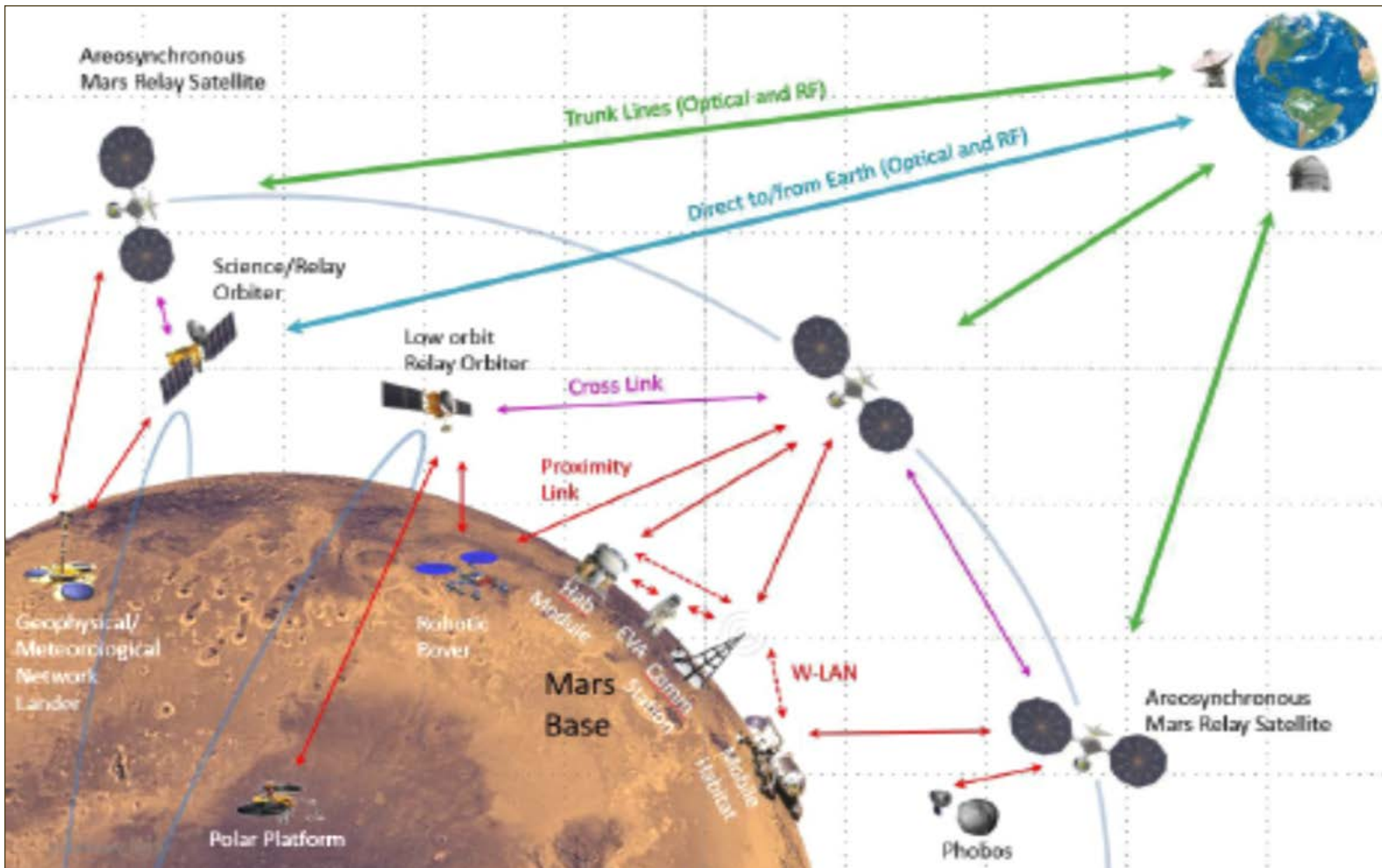


Figure 15. Notional Mars Architecture.

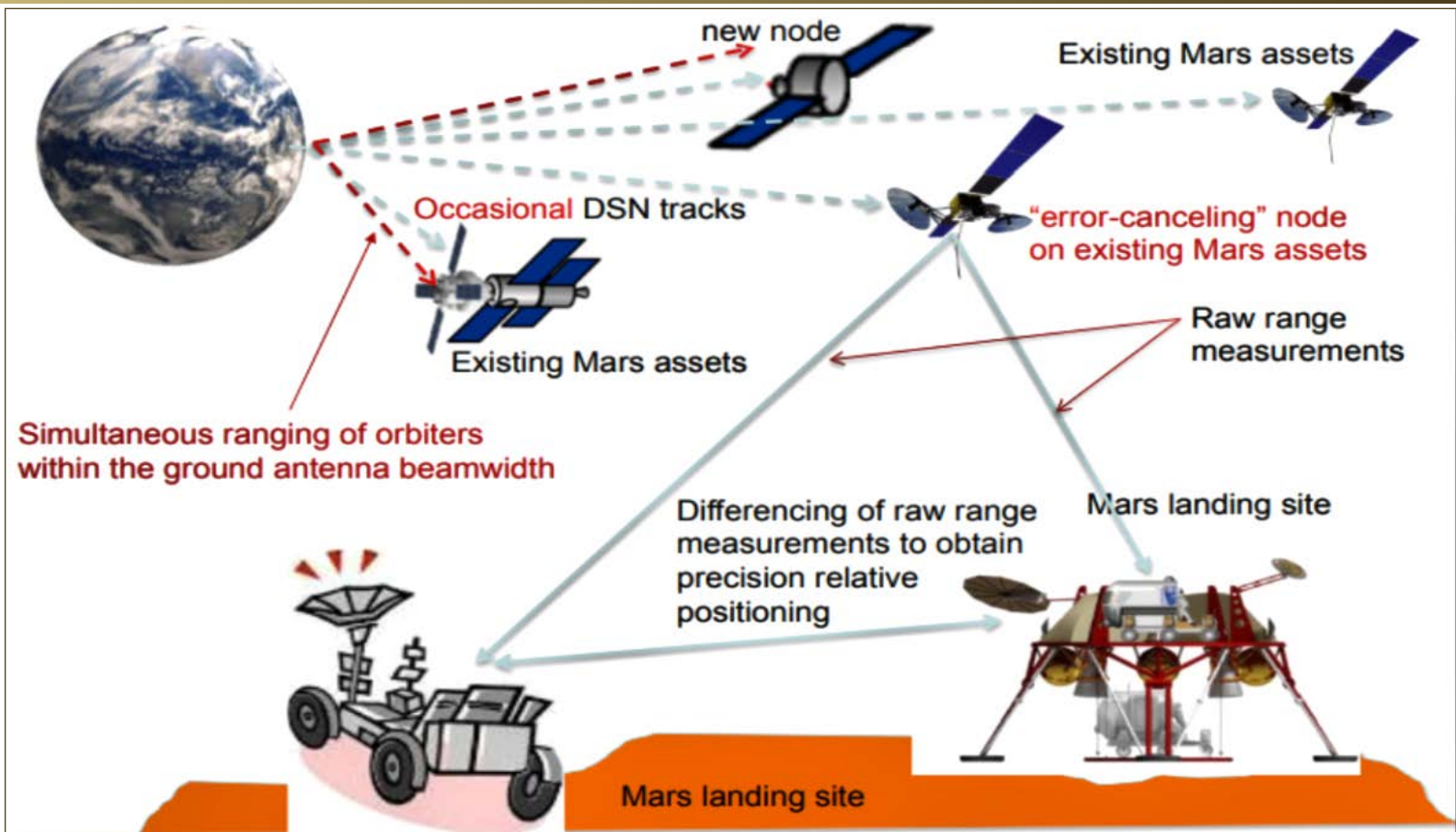


Figure 16. Schematic of MRNSS architecture: Key concept of in-situ regional navigation Services — Differencing of Range Measurements to Eliminate Common Bias.

A favorable Mars relay network architecture option is to have two aerostationary orbiters that are within the line-of-sight of the landing site, and yet have enough angular distance such that at least one of the orbiters would be able to provide continuous communication coverage to the landing site during solar conjunction events. A deep space habitat (DSH) has been proposed, which would orbit around Mars in an inclined 48-hour circular orbit. The DSH would act as a staging and monitoring facility for the human Mars surface explorations, and to perform tele-robotic activities on Mars, Phobos, and Demos [39]. (See Figure 15 on the previous article page.)

Taking into account the need to provide only regional coverage on the Mars surface, and the expected deployment of areostationary relay orbiters and other orbiting assets that hover over the Mars landing site, we propose to leverage on the Mars orbiting infrastructure build-up to establish a Mars Regional Navigation Satellite System (MRNSS). With the augmentation of one or more low-cost dedicated Mars navigation satellites that trace around a figure-8 path in areosynchronous orbits, there can be four or more navigation nodes with sufficient geometric diversity that could enable accurate localization in the vicinity of the Mars landing site.

Note a three or four ground stations “looking upward,” and tracking a constellation of spacecraft that is composed of one reference spacecraft and multiple target spacecraft operating at the

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NOTES AND REFERENCES

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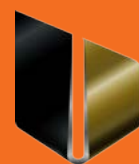
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