A HARRIS SPACE AND INTELLIGENCE SYSTEMS PUBLICATION

insights

for a better world

Ensuring SUPERIORITY in space

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FEATURES:

HARRIS® TECHNOLOGY TO CONNECT, INFORM AND PROTECT™

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[Executive Note]

Ensuring Superiority in Space

"Harris has been focused on the 'high frontier' since the beginning of the Space Age….Today we support some of our nation's most important space missions."

The Space Race of the 1950s and 1960s has nothing on the race that is going on today. While serious in that it recognized the role of space in national security, that first race for space superiority was limited to two entities, the U.S. and the Soviet Union, and the domain itself was benign and uncluttered. Today there are many entities, each with their own agenda, that have access to space. There are decades of debris to monitor and avoid, and more objects entering orbit every year. Combined, these make the mission of protecting our nation's assets in space and our access to space far more complex—and challenging—than ever before.

Harris has been focused on the "high frontier" since the beginning of the Space Age, when we supplied telemetry for early space vehicles. It is one of the key reasons our headquarters are on the Space Coast. It is also one of the reasons we have more than 700 of our professionals living and working in Colorado Springs, the home of Air Force Space Command. Today we support some of our nation's most important space missions with sensors; ground systems and processing capabilities; analytics for better decision making; and ground system maintenance, sustainment, and modernization services.

This edition of *Insights for a Better World* highlights key Air Force space missions that Harris Space and Intelligence Systems supports. In "**Protecting America's Space Assets**" on page 2, we explore the big-picture perspective of space situational awareness (SSA), focusing on how Harris is helping the Air Force keep legacy sensors "in the fight," expand their capabilities, and even move toward the ideal end state of dynamic SSA.

Weather is a critical part of the warfighter's situational awareness, and the retirement of the Defense Meteorological Satellite Program means a new approach to weather observation and prediction is essential. We discuss some of the exciting new capabilities possible in "**Next-Generation Weather Intelligence**" on page 6.

Our military forces—indeed the world—depend heavily on the positioning, navigation, and timing (PNT) services of the U.S. Global Positioning System. "**Navigating the Future of PNT**," page 10, considers ways to mitigate dependency on one of the world's most ubiquitous utilities.

Small satellites mean big opportunity for getting more missions into space. But doing this affordably has been a barrier. Dan Gillen, from **Harris Spaceport Systems**, shares Harris' unique offering on page 13.

It takes skilled and prepared warfighters to ensure superiority in space, and the Air Force is ensuring that those responsible for defending our freedom of action in space are at the top of their game through a new, dynamic "train-like-we-fight" simulation tool. Read more about this in "**Under the Big Top: A New Approach to Space Control Training**" on page 14.

With the acquisition of Exelis in 2015, Harris consolidated most of the space-related businesses of both companies into the Space and Intelligence Systems business segment. Bill Gattle, our segment president, provides insights into how we are "**Evolving Harris' Space and Intelligence Business**" on page 16.

To quote General John Hyten, commander of the U.S. Strategic Command, "Little if any good can come from a war in space. All that being said, the only way to avoid such a war is to always be prepared to defend ourselves. Always." From sustaining and improving critical ground systems to creating the space-based sensors that provide valuable insights for the warfighter, Harris is committed to helping protect our nation's right to the "high frontier."

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PROTECTING AMERICA'S SPACE ASSETS

Protecting the United States' space assets has become essential to ensuring the safety and security of the nation and its allies. At the heart of this mission is space situational awareness. With the increasing amount of debris in space, the proliferation of space capabilities among governments and commercial entities, and the shrinking size of space vehicles, the fight is on to cost effectively advance our nation's aging space situational awareness ground infrastructure.

Space situational awareness is the foundation for our mission success," then Lieutenant General John W. "Jay" Raymond told attendees at the 2014 Mitchell Institute for Aerospace Studies' seminar on The Value of Space to the Warfighter Command and Control and Space Situational Awareness.

At the time, Raymond, now Commander of Air Force Space Command, was 64 days into his assignment as Commander of the 14th Air Force and the Joint Functional Component Command for Space. Even in that short period of time, his command had, he reported, generated some eye-opening statistics, including the detection, threat determination, and reporting of 145 ballistic missile launches; detection and tracking of 16 space launches; processing of 25.2 million space observations; and issuance of 200,000 warning notifications of potential conjunctions in space.

"SSA [space situational awareness] is a really tough business, and it's getting tougher each day," said the general, citing the growing number of objects in space, the decreasing size of satellites, the rising number of spacefaring nations, and the increasing capability of individual satellites as factors contributing to the complexity of the space situational awareness mission today.

No Longer a Benign Environment

Today, NASA's Orbital Debris Program Office reports more than 21,000 pieces of orbital debris larger than 10 cm, an estimated 500,000 space debris particles between 1 and 10 cm in diameter, and more than 100 million particles smaller than 1 cm. Combine these numbers with more than 1,000 active satellites, and space is looking more crowded every year.

"Objects in orbit travel at very high velocities relative to each other. Even the smallest object can have a catastrophic effect on an active satellite," says Dan Jaworowski, director of Harris Space Superiority and Ranges programs. Jaworowski is part of the Harris Space and Intelligence Systems team supporting the Air Force Space Command mission. While tracking and cataloging all of those manmade objects in space have never been more important, Jaworowski has also seen an increased emphasis on identifying threats, like signal jammers and antisatellite weapons, and growing capabilities in space from U.S. adversaries.

"To quote General John Hyten, commander of U.S. Strategic Command," Jaworowski adds, "'we're moving out of a mindset of operating in a permissive, benign environment to one focused on threats to our space systems.[1]'"

Keeping Legacy Sensors in the Fight

The Air Force has been building its space situational awareness infrastructure—a global network of ground-based sensors and dependable command and control system—since the late 1950s, when Project Space Track was started to track artificial Earth satellites and manmade debris. Today, engineers and scientists from Harris are working to keep critical, aging sensors like the Perimeter Acquisition Radar Attack Characterization System (PARCS) and the PAVE Phased Array Warning System (PAVE PAWS) viable and in good working order 24 hours a day, 7 days a week.

"It's a real challenge to keep all of these disparate, legacy sensors in the fight, doing the heavy lifting for SSA. Parts requiring replacement become obsolete. The needs of the warfighter change," says Nathan Nipper, engineering manager for Harris Space Superiority programs. "So we look for innovative ways to make sure everything works seamlessly and to modernize in the most cost-effective way possible."

U.S. Air Force photo by Airman 1st Class Krystal Ardrey

At the Joint Space Operations Center (JSpOC), U.S. and Allied forces keep a watchful eye on orbiting objects, employ joint space forces, and help integrate space power into military operations.

In fact, a team of Harris systems engineers and scientists come together regularly to discuss user insights and share knowledge that could inspire new solutions that would serve the Air Force and its space situational awareness mission. "We have two primary areas of focus: potential new threats and how to respond to them, and emerging technologies that can address future mission needs," Nipper says.

An incremental approach to migrating services onto updated platforms and inserting new technologies lets the Harris team address very specific customer needs relatively quickly. Nipper explains: "Typically, acquisitions for radar and optical systems—from RFP [request for proposal] to fielding—can take many years. But because we fully understand the legacy systems, the customer's mission, and emerging technologies, we're able to systematically upgrade SSA systems in significantly less time."

Recent modernization efforts have upgraded early warning radar system hardware and software at Thule Air Base, Beale Air Force Base (AFB), and Royal Air Force Fylingdales to improve sensor coverage. Planned upgrades at Eglin AFB not only will help extend the operational life of the AN/FPS-85 phased array radar there, but also will exploit new technology. "We're bringing new, tactically significant capability for low-Earth-orbiting and geostationary satellite missions," says Morgan Nicholson, Harris' modernization technical lead at Eglin. "We are nearly doubling the data throughput capacity and the number of targets that the radar can handle and enabling better detection of small objects, like microsats."

Improvements are also under way for the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system. Here, the Harris team is incorporating modular components that enable new technologies to be inserted without "breaking" the overall system architecture. The team is also adding the capability to expose more data collected by the sensor.

Air Force Maui Optical and Supercomputing Observatory

Through successful, ongoing sustainment, modernization, and improvement efforts, legacy space surveillance systems are able to "stay in the fight"—even after multiple decades of service.

Eglin Air Force

RAF Fylingdales

"Previously, the GEODSS system could primarily report just the location of resident space objects or metric observations," says Len Calabretta, strategic plans manager for Harris Space Situational Awareness. "Now the Air Force will be able to add services that will improve the capability of the GEODSS system to characterize these objects. It becomes a much more tactical system that can support anomaly and threat detection—one of today's critical needs. Modularity will deliver significant life-cycle cost savings, while supporting changing mission requirements."

Expanding Capabilities

From the Naval Support Facility Dahlgren, Virginia, Air Force Space Command's 18th Space Control Squadron, Detachment 1, supports the nation's Distributed Space Command and Control System - Dahlgren, known as DSC2-D. DSC2-D is the alternate command and control node for the Joint Space Operations Center (JSpOC) Space Situational Awareness mission, which tasks the worldwide sensors in the Space Surveillance Network with detecting, tracking, and observing orbiting objects larger than 10 centimeters. Data from these 31 sensors is then processed, cataloged, and analyzed.

Now a new tool, the Non-Traditional Data Pre-Processor (NDPP), is expected to significantly up the game for the JSpOC and DSC2-D with a big boost in data obtained from other Department of Defense agencies, universities, foreign governments, commercial satellite flyers, and commercial ground sensors.

"NDPP will leverage billions of dollars in current U.S. government investment in other sensors and systems and billions more in foreign and commercial investment," says Megan Monteith, who leads the Harris program working to deliver a successful NDPP. "Organizations like the JSpOC, the JICSpOC [Joint Interagency Combined Space Operations Center], and the 18th Space Control Squadron will be able to exploit and fuse data from literally thousands of new sources to give the space warfighter a much richer operational picture and the basis for better decision making."

To do this, NDPP will need to reduce the amount of direct human involvement. "We are working to incorporate more automation and reduce the tasking cycle time so that useful data gets into the hands of those that need it more quickly," adds Monteith.

Moving toward Dynamic Space Situational Awareness

For many years, the twin goals of space situational awareness have been custody and persistence—being able to find resident space objects in orbit and then keep track of them over time. Today the holy grail of space situational awareness takes this one step further: to more precisely characterize those objects—including more and smaller objects—and monitor any changes they might make.

By sustaining and incrementally modernizing legacy systems, leveraging outside resources, and getting data into the hands of the warfighter more quickly, Air Force Space Command is evolving its legacy space situational awareness infrastructure to be more responsive to the needs of today's warfighters.

"We must know where objects are, who owns them, and what capabilities they represent," Admiral Cecil D. Haney, U.S. Strategic Command Commander (now retired), told his audience at the 32nd Space Symposium. "We simply cannot risk denied access to a domain that is so vital to U.S. national security." ■

[1] *Gen John Hyten on "Overcoming Our Space Vulnerabilities," 2014 Space and Missile Defense Symposium*

EMERGING TECHNOLOGIES

Advancing America's space superiority mission means pushing the envelope in technology, capability, and their delivery times. Three innovative solutions under development at Harris could pack a lot of punch toward getting future missions into space faster.

Advanced Optical Components for Space

Traditional optical systems that deliver the detailed imagery needed by the military and intelligence communities can require a considerable amount of time and money for delivery. Today, Harris is building on its experience in high-precision optics to solve this problem by applying innovative processes and new materials to significantly reduce production time and cut recurring and nonrecurring costs by more than half.

For example, the traditional mirrors that are integral to space-based imaging systems start as heavy slabs of glass, which are slowly ground into shape and polished to a high degree of precision. Harris is now developing technologies to replicate, construct, and even 3D print advanced mirror components. Leveraging new, enabling materials such as advanced composites, Harris is further advancing mirror technology used for space-based imaging. Besides being more rapidly produced, these optics are also lighter in weight—always an advantage for space missions.

High-Quality Imaging Payloads for Small Satellites

The SpaceView™ line of high-performance imaging payloads is making it more practical and affordable than ever to obtain quality image intelligence. SpaceView™ was developed based on Harris' legacy high-end optics, patented structures, and image-quality solutions. With an innovative compact design, it offers high-resolution imaging payloads for small satellites and can even support multiple missions with payloads configured with two different sensor modalities.

Various sensor options enable scanning image collection for wide area coverage or temporal offerings that include motion imagery or full-motion video. Broad spectral capabilities range from visible (panchromatic or color) to multispectral imagery to infrared. When launched as part of a small satellite constellation, SpaceView™ can provide more frequent revisit rates over areas of interest. Processing and compression solutions that are aligned with system and mission needs are also available.

HyperCube™ 3D Wind Measurement

The precision of today's weather data is improving prediction models; however, the availability of accurate wind data has lagged behind. Drawing upon existing sounding technology, Harris has developed the HyperCube™ 3D sounder as a cost-effective solution.

This space-based instrument measures the speed, direction, and elevation of wind in Earth's atmosphere. Designed for a cubesat configuration, HyperCube™ is much smaller and less expensive than LiDAR wind measurement programs and offers a more expedient implementation alternative to complex LiDAR programs.

Plus HyperCube™ provides hundreds of hyperspectral bands for the best instrument resolution in the small satellite market. It delivers more vertical layers of wind vector data at fine spatial resolution, resulting in more accurate data than other available solutions.

NEXT-GENERATION WEATHER INTELLIGENCE

Advancements in weather monitoring can mean better forecasts for military operations. Here are key technologies delivering the next generation of environmental intelligence.

What do George Washington's Crossing of the Delaware River, D-Day, and the capture of Osama Bin Laden have in common? All three of these pivotal military events relied on weather intelligence for mission success. Today more than ever, accurate weather forecasting is critical to the protection and success of our warfighters. Fortunately, new technologies—from space to ground—offer opportunities for more accurate and timelier weather information that can greatly improve our military's situational awareness.

GOES-R: A Transformational Change in Hemispheric Weather Intelligence

As the next generation of the National Oceanic and Atmospheric Administration's (NOAA's) weather forecasting system, the Geostationary Operational Environmental Satellite-R (GOES-R) program promises forecasters a significant increase in the quality, quantity, and timeliness of weather imagery and data for the continental United States and the Western Hemisphere.

"It starts in space, with the Advanced Baseline Imager (ABI), the primary instrument on GOES-R for imaging Earth's weather, climate, oceans, and environment," states Eric Webster, vice president and general manager of Harris' Environmental Solutions business. "ABI is one of a class of Harris instruments delivering the most advanced meteorological sensing capability in the world for operational weather forecasting. It offers three times the spectral information, four times the spatial resolutions, and more than five times the speed of coverage provided by the previous GOES system."

ABI's 16 sensing channels collect imagery in the visible, near-infrared, and infrared spectrums. This imagery can then be analyzed to provide information about conditions like cloud cover, wind, humidity, ozone, vegetation, and ice cover. "ABI can monitor three times more atmospheric conditions than current geostationary imagers, plus discern objects as small as one-half a kilometer—another asset for enhancing situational awareness," shares Webster.

Scanning Earth one swath at a time and interleaving those swaths, ABI simultaneously collects full-disk hemispheric images every 15 minutes, regional images every 5 minutes, and severe weather images every 30 seconds. "ABI can track a single storm at full resolution, while continuing to collect continent-wide data and imagery," Webster says. "Plus, it's the only weather instrument that can be configured on orbit to provide custom scanning. With this type of flexibility and persistence and with the frequent temporal refresh, relevant data is timelier and forecasts are more accurate. This is a real advantage for activities like target selection and operational mission planning."

OCONUS Applications

ABI's transformative technology is also impacting the quality and quantity of weather information outside of the continental United States and the Western Hemisphere. An ABI class instrument called the Advanced Himawari Imager (AHI) has been operational for the Japan Meteorological Agency since July 2015, covering East Asia and the Western Pacific from Japan's Himawari-8 meteorological satellite. A second AHI was launched on board the Himawari-9 satellite in February 2017. AHI data is available to national meteorological services outside of Japan through the HimawariCloud internet service and HimawariCast data rebroadcasts. (See **Nowcasting with WxConnect** on page 8.)

South Korea's planned Geostationary Korea Multi-Purpose Satellite - 2A (GEO-KOMPSAT-2A) will also have on board an ABI class instrument known as the Advanced Meteorological Imager (AMI). GEO-KOMPSAT-2A and a second satellite, GEO-KOMPSAT-2B, will replace the Communication, Ocean and Meteorological Satellite (COMS-1) in its mission to observe the weather and ocean environment and strengthen the national capability to monitor the environment around the Korean Peninsula.

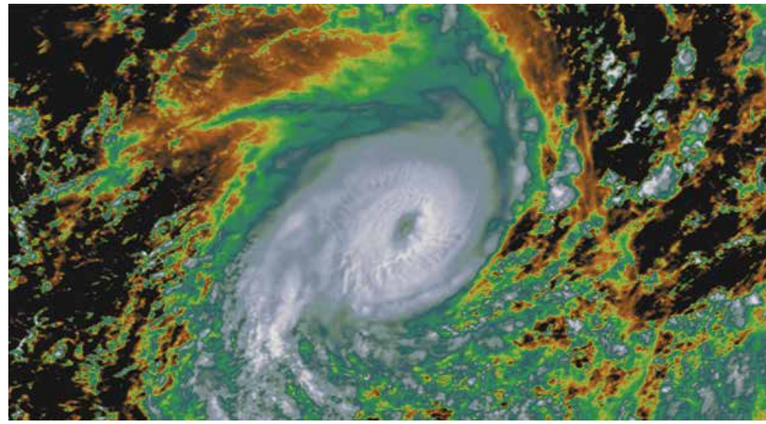


Image from Harris' AHI instrument on board Himawari-8

"A strategically placed ABI class sensor would provide a long-term solution over western Asia and the Indian Ocean, where military operations are currently vulnerable to the aging and limited coverage of existing satellites," Webster says. "ABI's high spatial resolution and rapid refresh capability directly address key defense weather requirements critical to protecting the warfighter and ensuring mission success."

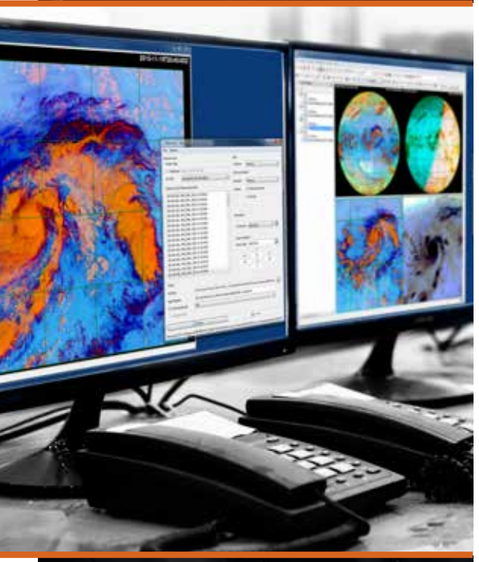
Processing and Delivery of Real-Time Environmental Intelligence

With the deployment of ABI class sensors, forecasters have the opportunity to leverage an unprecedented amount of detailed data and imagery. "The volume and speed of information from the ABI instrument is like switching from black and white to high-definition TV," says Romy Olaisen, vice president of Harris' Enterprise Ground Solutions. "It requires a whole new way of receiving, processing, and disseminating the data."

Olaisen leads the Harris business area that designed, installed, and will operate the GOES-R ground system responsible for receiving the data from six instruments, including the ABI, and delivering it to the National Weather Service and more than 10,000 other direct users. The system architecture provides a true enterprise ground solution; algorithms and computing resources are shared within an open, service-oriented architecture that allows for the easy insertion of other sensor data or algorithms from other satellite missions.

"This flexibility means that other organizations can leverage NOAA's GOES-R ground system investment and the lessons learned from that effort for weather and other integrated sensor applications," says Olaisen.

Together these innovations in both sensor and ground technologies are particularly well suited to serve military operations worldwide. For example, ABI technology supports munitions selection by detecting cloud heights, assists maritime operations with better hurricane intensity estimates and sea ice monitoring, and helps troops on the ground with measurements of snow depth. It also provides rapid updates for thunderstorms and severe winds that can take down unmanned aerial vehicles.



NOWCASTING
WITH WXCONNECT™

There's no doubt that ABI class sensors can greatly improve the ability of meteorologists to predict the weather, but getting that data into their hands quickly can be a challenge. With the IntelliEarth™ WxConnect™ system from Harris, forecasters have the ability to directly receive GOES-R and HimarwariCast environmental satellite information without reliance on terrestrial communications. WxConnect™ processes the high-density data streams so that real-time, standards-based products can be generated for distribution, data fusion, advanced analytics, and visualization.

Built on open standards, WxConnect™ systems are modular and scalable, and compatible with standard industry weather visualization and forecasting applications. Harris ENVI® visualization software is available for WxConnect™ systems to assist in creating custom imagery. Powered by IDL® software, Harris developed an interactive, real-time Advanced Product Preview (APP) tool for WxConnect™ to more effectively utilize the 16 channels of imagery.

Advances in Earth-observation Sensing from Polar-Orbiting Satellites

Low-Earth-orbiting satellites have long been the workhorses for collecting the weather data used to support global military weather missions. With the retirement of the 60-year Defense Meteorological Satellite Program (DMSP) and the new Weather Satellite Follow-on program taking shape, the U.S. Air Force has the opportunity to incorporate recent advancements in polar-orbiting electro-optical/infrared (EO/IR) imaging capability, believes Eric Webster.

Webster points to the Enhanced Advanced Very High Resolution Radiometer (AVHRR) as an example of what "could be" for tomorrow's Air Force weather mission. "AVHRR has been the primary instrument on the NOAA Polar Operational Environmental Satellite—or POES—system," he explains. "It produces images used not only to track storms, but also to map water boundaries, lake volume fluctuations and snowmelt, and monitor sea surface temperatures."

Harris has evolved the spectral capability of AVHRR since it first flew in 1978 on the TIROS-N satellite, with AVHRR/2 serving NOAA-7 missions and AVHRR/3 on NOAA-15 and MetOP-1, Europe's first polar-orbiting satellite for operational meteorology. Today AVHRR/3 is internationally recognized as the definitive operational imager for global weather data. With six multispectral channels, the radiometer delivers additional capabilities, such as low-light energy detection, snow/ice discrimination, forest fire detection, and global vegetation indexing. Continued improvements in the technology are available on the more recent Enhanced AVHRR and include four additional channels, detectors that achieve a 1 km constant footprint, and onboard image processing capability.

"Whereas DMSP has had a two-channel operational line scanner, the Enhanced AVHRR has 10 channels for much improved spectrum detection. This means you can distinguish between things like

Installation of ABI on GOES-R

high clouds and low clouds, and between low clouds and snow," says Webster. "Technology like this—advanced, but with a high technology readiness level and a flight-proven foundation—can be a low-risk sensor solution for a DMSP follow-on program."

Another type of Earth-observation sensor is the sounder, which uses emitted infrared energy to "look" vertically through the atmosphere. The new generation of meteorological sounders became operational in 2011 with the launch of NOAA's Suomi National Polar-orbiting Partnership (Suomi NPP) satellite and its onboard instrument, the Cross-track Infrared Sounder (CrIS). According to NOAA, CrIS represents "a significant enhancement over NOAA's legacy infrared sounder—High Resolution Infrared Radiation Sounders (HIRS)."

Used daily by the National Weather Service, CrIS scans a 2,200 km swath width with 30 Earth-scene views, drawing upon 2,211 spectral channels over three wavelength ranges. "This provides the data necessary to produce high-resolution, three-dimensional temperature, pressure, and moisture profiles that improve numerical prediction models for both 'nowcasts' and long-range forecasting," explains Harris Chief Solutions Engineer Ron Glumb, part of the Harris team that developed and built the CrIS instrument. CrIS also measures atmospheric chemistry and can detect the concentration of greenhouse gases, like carbon dioxide, in the atmosphere.

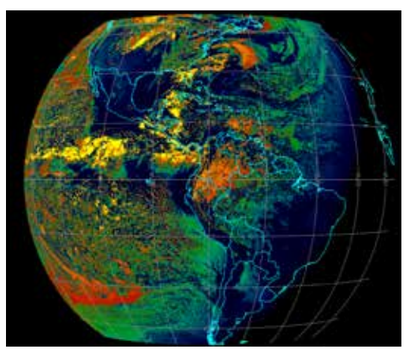
Over the long term, NOAA expects that CrIS data will help improve understanding of climate phenomena, such as El Niño and La Niña, including the continental transport of greenhouse gases.

In addition to serving the Suomi NPP effort, CrIS will play a key role in the new Joint Polar Satellite System (JPSS), a collaborative effort between NOAA and NASA that will continue the weather and environmental observations of the Suomi NPP satellite and its predecessor, the POES series.

Filling the Local Weather Information Gap

Anyone who has run a field operation knows just how quickly weather can change and how varied it can be even between areas no farther apart than a city block. Regional radar is helpful, but it does not always provide the detail needed to make optimal decisions at a local level.

A new ground-based environmental intelligence tool called Helios® fills this gap, according to Eric Dixon, senior product manager at Harris and one of the developers of Helios®. "It works by taking imagery from existing public and private video cameras and integrating it with National Weather Service warnings and other weather data," he explains. "It then quickly analyzes all of this using a combination of machine learning and traditional image science, and provides users with real-time identification and classification of weather changes." With specialized analytics for visibility, road wetness, and road snow, Helios® is particularly helpful for users who need to transport personnel and cargo or respond to emergencies. "By providing real-time, accurate weather information, Helios® supports effective decision making that improves safety and minimizes costly delays," Dixon says.



Simulated GOES-R ABI imagery for "blue" visible band #1

Harris Helios® is being incorporated into the development of commercial autonomous vehicles as part of vehicle safety applications to feed road condition information in support of vehicle decision making. Similarly, in the assisted driver market, Helios® feeds "look ahead" road condition information to drivers to enhance safety and routing. For military operations, Helios® can be adapted to unmanned ground vehicles for a wealth of new environmental intelligence. Additionally, Helios® analytics can identify non-traversable obstacles and notify the navigation system to divert the vehicle.

A Key to Military Victory

In talking about weather intelligence and its impact on the warfighter, Eric Webster refers to a popular quotation taken from the ancient Chinese treatise, *The Art of War*. "It translates as, 'Know yourself, know your enemy, your victory will never be endangered. Know the ground, know the weather, your victory will then be total,'" he recites. "This is as true today as it was in the 5th Century, B.C., when it was written—and the advantage is with those who have the most accurate, up-to-date information.

"Just as the military landscape and warfighting environment have evolved, so too has our ability to monitor the weather in much greater detail with more frequent updates," says Webster. "Today's satellite and ground capabilities represent a quantum leap in the accuracy, timeliness, and effectiveness of weather information for mission planning and execution. Our servicemen and women deserve only the very best in environmental intelligence." ■

WHAT'S NEXT?
A GEOSTATIONARY COMBINED SOUNDER/IMAGER

What if you could have one system that combines the spatial resolution and update rates of an Advanced Baseline Imager (ABI) class instrument with the spectral profile detail and accuracy of a hyperspectral, advanced Fourier transform spectrometer like NOAA's Cross-track Infrared Sounder (CrIS) or EUMETSAT's Infrared Atmospheric Sounding Interferometer (IASI)?

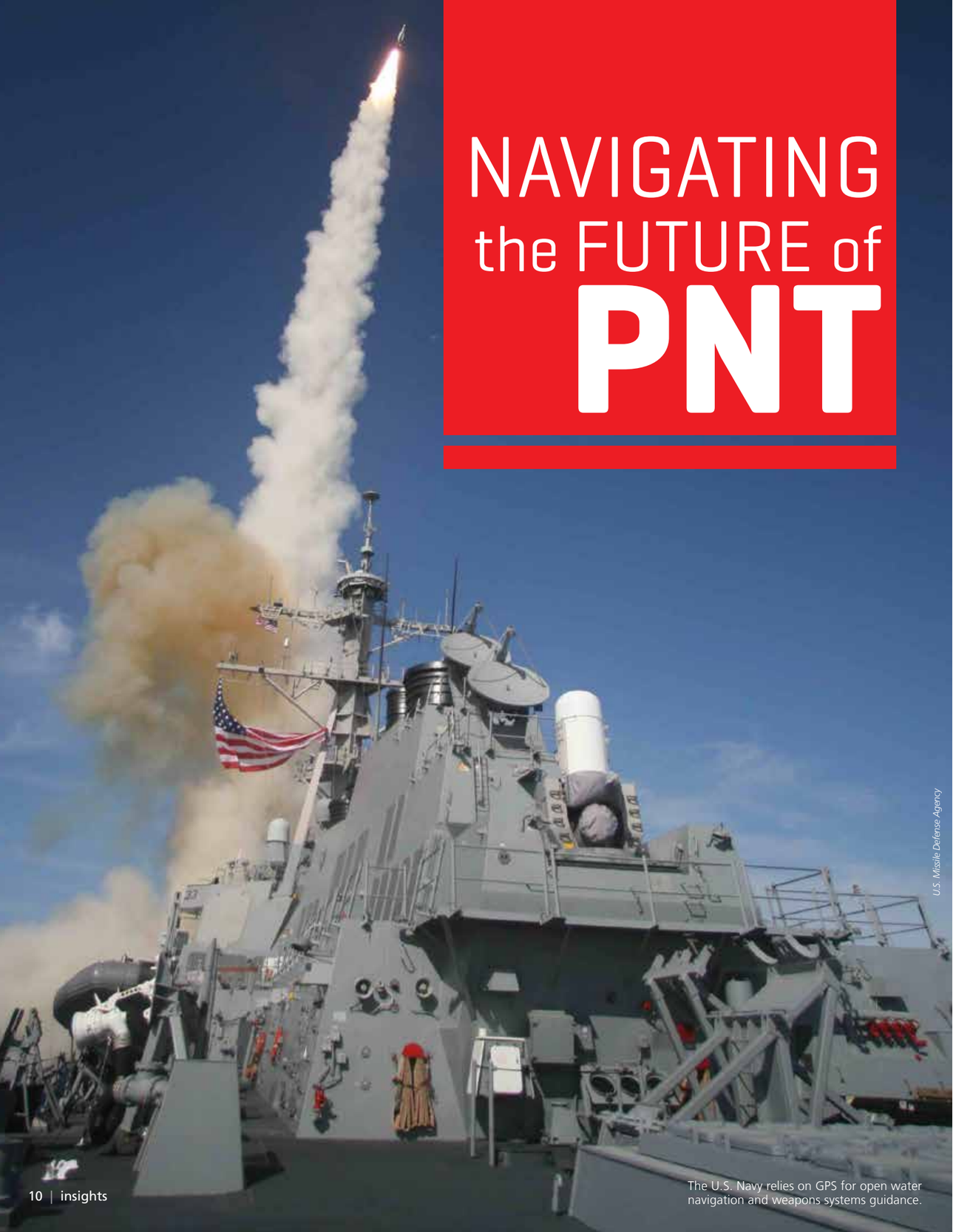
"You'd get the ABI-based Geostationary Combined Sounder/Imager, or CSI," says Ron Glumb, chief solutions engineer for Harris Environmental Solutions. "It's a hyperspectral instrument that offers the best of both worlds: full-Earth-disk (hemispheric) images every 10 minutes, regional images every 5 minutes, and precise mesoscale-size area soundings every minute for advanced (up to 6 hours) warning of severe storms plus near-real-time, three-dimensional winds."

CSI will also provide the first geostationary day/night band images. "All this means faster, 24-hour-a-day tracking coverage of active weather, like tornadoes, hurricanes, and other severe storms," Glumb adds.

The CSI is being developed under a Harris internal research and development effort. The team shared their progress at the 21st Satellite Meteorology, Oceanography and Climatology Conference. "Results are showing that the CSI easily meets ABI imaging requirements and has noise equivalent differential radiance (NEdN) levels similar to CrIS," Glumb reports.

According to Glumb, CrIS' on-orbit NEdN has exceeded mission requirements and performed better than other hyperspectral sensors in orbit. Key technologies for CSI have been demonstrated at a technology readiness level of 6.

NAVIGATING the FUTURE of PNT



U.S. Missile Defense Agency

The U.S. Navy relies on GPS for open water navigation and weapons systems guidance.

It is no secret that the Global Positioning System we rely on for everything from car navigation to military operations, cell phone service to banking, is highly vulnerable to outages—both unintentional and intentional. Ensuring future positioning, navigation, and timing services will likely depend on multiple strategies.

When the U.S. Air Force was tasked with the design of the NAVSTAR Global Positioning System (GPS) more than 40 years ago, the system was intended primarily "to deliver weapons precisely on target and to reverse the proliferation of navigation systems in the U.S. military," according to Rick W. Sturdevant, Ph.D., deputy director of history for U.S. Air Force Space Command, in *The Societal Impact of Spaceflight*. Today, GPS is not only integral to military operations, it is also one of society's most ubiquitous global utilities and has become essential to important functions like stock market exchanges and power grid management.

Such dependency brings great risk, and military agencies and experts in positioning, navigation, and timing (PNT) technologies are looking at numerous ways to address the challenge. "Like most things in the complex world we live in, there is not likely to be just one solution," says Harris Vice President Pat Seamon.

Shoring Up GPS

According to Seamon, one of the strategies being pursued is improving GPS itself. "GPS signals were weak by design," he advises. "The satellites are solar powered. To constantly produce and broadcast their signals requires balancing energy requirements for generating them, the equipment, and other resources needed to operate the GPS mission. That has meant some give and take when it comes to signal strength. Plus radio waves weaken as they come through the atmosphere. This all makes them very vulnerable to disruption."

Anyone who has used a handheld GPS device knows how GPS signals can be blocked in areas flanked by tall buildings or covered with thick foliage. Of greater concern, though, is the use of jamming devices despite federal laws prohibiting their marketing and operation. As recently as May 2016, the Federal Communications Commission fined a Chinese company $34.9 million for illegally marketing and selling devices that jam signals like GPS to U.S. consumers.

As a result, expectations for the next generation of GPS satellites are improved signal strength and accuracy, "We now have the capability to deliver signals that are three times stronger than those from today's satellites. This enables a location accuracy to 3 feet, compared to today's 10-foot accuracy," explains Seamon, whose team has been working to advance PNT technology since the program's earliest days. "It also means overall better coverage in those urban canyons and forests."

Another benefit of stronger signals is that they become more impervious to jamming. For military personnel, who use a different, more resilient signal, Seamon's team has developed a signal that provides an eightfold increase in anti-jamming power.

Military operations rely on precise PNT capabilities to minimize collateral damage.

U.S. Air Force photo by Staff Sgt. David Carbajal

Strengthening GPS signals and employing alternative PNT strategies will help protect warfighters in the future.

A Better "Brain" for PNT Payloads

Advancements like these are the result of applying more than four decades of Harris PNT research and development, and even longer experience in radio frequency and satellite communications to build a better "brain" for global navigation satellite systems, states Senior PNT Systems Engineer James Phelan. "Today it's important that missions can support spiral life-cycle development so that new technologies can be 'gracefully' incorporated," Phelan says. "What we have come up with is a modular, fully redundant system that uses independent circuit cards for critical algorithms and data processing, command and control, maintenance, and telemetry functions."

While GPS has been very successful, the time frame to add new signals has been about 10 years—an eon in today's fast-paced world. According to Phelan, Harris' research has led to the ability for military users to add new codes and signals. "A flexible code generation system can add resiliency to the system to adapt to changing needs and enable the military to respond to threats more quickly," he adds.

Future PNT payloads are likely to become more digital—maybe even all-digital," says Phelan. "And components like solid-state gallium nitride (GaN) transmitters could make a difference in signal efficiency size, weight, and power requirements."

GPS Alternative

The recognized limitations and vulnerability of GPS signals and satellites have prompted military strategists to look for ways to augment their PNT capabilities. With the goal of protecting warfighters in contested environments, the U.S. Army has initiated the Assured PNT (A-PNT) program, a system of systems approach to provide innovative and robust terrestrial-based PNT solutions through use of mounted platforms; dismounted soldiers; anti-jam antennas; and pseudo-satellites, or pseudolites, small ground-based transceivers for broadcasting location information.

"Then there's the issue of an alternative source for precise timing, which is critical for navigation, synchronizing operations, and time-stamping," comments Harris System Engineer Huascar Ascarrunz. "The sole dependence of society on GPS time for critical infrastructures was documented as a long-term national security risk in the 2011 National Risk Assessment."

For this reason, Harris is investing research and development funds and engaging both the government and the Stanford University Center for PNT to demonstrate a backup timing system for the continental U.S., says Ascarrunz. "We envision a robust network that leverages multiple signals of opportunity—not all space-based and some already available, like NIST WWVB[1]—to provide accurate, available, and trusted time anywhere in the continental United States. You can validate your GPS time source by comparing it with information from this alternative system or switch over to it entirely in the absence of GPS," he explains.

The Way Ahead

In the beginning, GPS' spread spectrum modulation, its encryption, and the physical security of space protected the integrity of the signal and its source. "But in 2000, GPS was made more accurate for commercial users and went from being the domain of only a few to being open to many," states Pat Seamon, citing both the threat of GPS signals being jammed and their vulnerability to being spoofed, or overridden by counterfeit GPS signals, as the result.

"We live in a world where threats can come from anywhere, where our adversaries are nimble—highly mobile and able to learn and adapt to changes quickly," Seamon observes. "We require resilient solutions to the systems we rely on the most. Strengthening our PNT capabilities and having backup strategies are not just smart, they are essential to our future safety." ■

[1]The National Institute of Standards and Technology (NIST) operates time signal radio station WWVB.

[By Dan Gillen, Program Manager, Harris Spaceport Systems]

A SPACEPORT FOR SMALLSATS

In its 2016 report on the global small satellite market, research firm Azoth Analytics validated what many in the space industry have sensed for years: there is a rising demand for small satellites, and it is driven by "surging customer demand for Earth observation, communication, space observation, [and] technology demonstration." In fact, the researcher stated, the market "is forecasted to grow at a CAGR of 19.54% during 2016-2021F, on account of rising applications."

With this kind of expected growth and the desire for the United States to maintain a leadership role in space, Congress' Space Subcommittee held a hearing in April 2016 on *The Commercial Space Launch Industry: Small Satellite Opportunities and Challenges.* In a summary statement, Subcommittee Chair Brian Babin (R-TX) said the subcommittee found "[o]ne of the largest barriers that small satellite companies face is the cost of launch."

Certainly industry is trying to do something about that. Rocket prices are dropping with increased competition and successful demonstrations of reusable launch vehicle technologies. Ridesharing—more than one satellite on a single launch vehicle—is another possibility, but faces its own limitations. The reality is that few options truly exist in the U.S. today for smallsat companies to get missions into space quickly and affordably. One of these is provided by Harris' commercial space operations.

The Most Efficient Path to Polar Obit

Most nano/microsatellites launch to a sun-synchronous or polar orbit. Harris Spaceport Operations, located at the southern tip of Vandenberg Air Force Base, is the only continental U.S. complex from which customers can launch their rockets directly at a pole without flying over any land masses while inside Earth's atmosphere. This is an important safety consideration and cost-savings benefit.

By partnering with companies that produce solid rockets, like Orbital ATK's Minotaur fleet, and through the use of an existing FAA Commercial Spaceport License, the Harris-operated spaceport has been able to provide affordable space launch opportunities to those who do not require more costly rockets or do not want the coordination hassles associated with "hitching a ride" as a secondary or tertiary mission.

On-site Processing Convenience

Many final launch preparations and checkouts cannot be completed until the satellite is at the launch site. For this reason, Harris Spaceport Operations includes a state-of-the-art integrated processing facility (IPF) that can accommodate all launch site processing and preparation activities, such as satellite fueling, battery installations, small explosives handling, radio frequency protection, and satellite encapsulation into nose cone fairings or other payload-carrying flight hardware.

With more than 12,000 square feet of on-site clean room space and three identical processing cells, the IPF supports multiple satellites simultaneously. Plus, customers have convenient access to several hundred office spaces so that office work and flight hardware processing can be completed in the same facility.

Ready for Launch

Harris has conducted nine successful launches and processed 15 satellites from the spaceport for government and commercial missions. With facilities and processes already in place to streamline costs, smallsat providers have a ready partner available to meet the needs of a new generation of spacecraft. ■

UNDER THE BIG TOP

A New Approach to Space Control Training

For most people, the term "Big Top" conjures up colorful images of circus entertainers performing amazing, high-energy acts inside a massive, mobile tent. For the U.S. Air Force, Big Top represents an entirely different, but no less exciting arena—one where future space control operators will be able to hone their craft using a dynamic, virtual, "train-like-we-fight" simulation tool.

A graphical user interface, connected to actual space control systems, contributes to a total-immersion training experience.

The use of space for transmitting communications signals—data, voice, internet and other media—has become commonplace, and with that has come the increased potential for adversaries to disrupt the flow of critical information and threaten national security. Now more than ever, warfighters responsible for ensuring U.S. freedom of action in space must be at the top of their game, ready for everything from protecting against system attacks to keeping up with technology innovations and new satellite spectral environments.

For years, the Air Force has conducted its space control testing and training at the secure and controllable environment provided by the Space Test and Training Range (STTR). "Now the Department of Defense is looking toward more virtual and constructive training and test environments," says Randy Miller, Harris program manager for Big Top. "Big Top is Air Force Space Command's solution to having the best trained space control warfighters in the world. It will complement the STTR by providing dynamic, closed-loop training simulations that connect into systems and provide what appears to be an authentic and dynamic representative spectral environment. With Big Top, you have the capability to develop realistic scenarios that reflect real-world signal environments to help better prepare warfighters for what they might have to face."

Greater Realism, Delivered Faster

Big Top will support four primary needs: unit-level training to keep space control operators up to date on systems and procedures; the simulation of Space Command assets in national-level exercises; formal user evaluations; and the ability to practice tactics, techniques, and procedures in a safe environment.

To create the most realistic environments possible for Big Top's training scenarios, Harris is using web-based, non-linear editing inspired by the latest movie production software applications. Signals will be generated through state-of-the-art software-defined radios (SDRs). A rules engine allows instructors to simulate real-world adversary reactions. "Today, getting realistic data for training can take weeks to months," explains Tony Harris, chief software engineer for Big Top. "Using Big Top assets, the Air Force can gather realistic satellite signal environments in a matter of hours." Signals synthetically generated using the SDRs can be added to further enhance training environments.

A graphical user interface with a high-fidelity display will connect to actual systems, contributing to a realistic, total-immersion training experience for space control operators. The interface will be the first instantiation of new web application guidelines for systems established by the Space Superiority Logistics and Sustainment Division. "Operators will feel as if they are really deployed in a live signal environment," Tony Harris says. "Plus the entire Big Top footprint will be small and modular—designed for easy deployment and lower sustainment and maintenance costs."

While Harris is developing sample scenarios for system testing, Air Force trainers will be ultimately responsible for creating the training exercises. Harris' train-the-trainer manuals and instruction will help them transition to independent operation of the new tool. Big-data analytical capabilities incorporated into Big Top will enable trainers to better evaluate trainees in a timely manner and to trend the effectiveness of space control operators within individual units across unit-level and national-level exercises.

Added Potential

While Big Top most certainly will help the Air Force achieve the sustainable and repeatable virtual range capability it wants, there is a potential bonus benefit to Big Top that was not written in program specifications. "Big Top has the ability to serve as a proving ground for new systems," believes Randy Miller. "It could be used to verify system requirements through simulation and test before a request for proposal is issued for new development capabilities—reducing risk and even saving time." ■

EVOLVING HARRIS' Space and Intelligence Business

An Interview with Bill Gattle, President, Harris Corporation Space and Intelligence Systems

Harris' Space and Intelligence Systems segment was formed when Harris Corporation acquired Exelis in 2015. Segment President Bill Gattle discusses the drivers and impacts of this business as it continues to evolve.

Q What are the primary drivers contributing to the evolution of Harris' Space and Intelligence Systems (SIS) today?

A The largest part of our business still comes from the U.S. government, for whom the world is presenting new challenges. Adversaries can come from anywhere, are mobile, and adapt quickly. They pose threats both on the ground and in space. As a result, our defense and intelligence community customers need greater situational awareness to respond to threats faster, and they need the information in an easily accessible, useful form. They also need to replace aging space technology with intelligent systems that are more responsive, cost effective, and less reliant on human operators. We are advancing smallsat technology, for example, and in two to three years, we will have it in a form we believe will be relevant for U.S. government challenges.

Q Harris Corporation's acquisition of Exelis in May 2015 was a major milestone in Harris' 120-year history. What has been the impact of that change on your business?

A It almost doubled Harris' size, making us one of the largest defense contractors and allowing us the ability to scale up to meet our customers' needs. It provided us with amazing technology and expertise to complement what Harris already had. For example, now we are arguably the most diverse and capable sensor house in the industry. That means we have an extraordinary ability to fly on practically any platform, acquire high-resolution geospatial imagery, process it, analyze and provide it in a form that everyone from farmers to Special Operations can use.

Our satellite payloads allow us to, among other things, track all the commercial aircraft and ocean-going vessels in the world, send the GPS signal on which millions of people and billions of dollars in commerce depend, and capture weather images for forecasts that mean the difference between life and death.

Our space and ground-based optics look into the farthest reaches of space, and when our antennas on satellites unfurl after the satellite is in orbit, millions of people can communicate more easily.

Q What else contributes to how you think about next steps for the Harris Space and Intelligence business?

A Global connectivity to the internet has drastically transformed how we do almost everything. I've seen projections that indicate there will be as many as 100 billion connections by 2025. How we use and protect this connectivity has to be at the forefront of our minds when it comes to solving our customers' problems.

The space industry is undergoing its own transformation as the demand for more affordable access to "the high frontier" is driving commercial entrepreneurs to invest their own money into new types of launch vehicles and prompting satellite owners to host more than just their primary mission payloads on their buses. The next wave of change will be in the use of small satellites—considered a novelty 10 years ago—and affordable payloads that rideshare on them.

Q Why do customers want to work with Harris?

A We have some very clear technology discriminators in the areas of remote sensing, ground systems and processing, and data analysis. We are also able to align how we work with how our customers want to buy—very important when our customers have so many needs. But I think it is our people who really make the difference. These knowledgeable scientists, engineers, and mission experts work side by side with our customers day in and day out with a "mission first" focus and a sensitivity to mission affordability. ■

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Harris Corporation is a leading technology innovator, solving customers' toughest mission-critical challenges by providing solutions that connect, inform and protect. Harris supports government and commercial customers in more than 100 countries and has approximately $6 billion in annual revenue. The company is organized into three business segments: Communication Systems, Space and Intelligence Systems and Electronic Systems. Learn more at harris.com.

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