AIR SAFETY 14
Containing blade-outs

OPINION 44
Why blockchain is powerful

SPACEFLIGHT 28
Dream Chaser attempts a comeback

AEROSPACE AMERICA

TRY THIS MONTH'S AEROPUZZLER PG 11

Fighting for the future

U.S. Army seeks to accelerate Future Vertical Lift PAGE 18

JULY/AUGUST 2018 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA Shaping the Future of Aerospace

MISSION-CRITICA

The U.S. Defense Department relies on data from civil, military and allied weather satellites to develop forecasts for troops carrying out a range of operations.

U.S. Defense Department

AL FORECASTING

The U.S. Air Force is in the midst of upending its decades-old approach of gathering life-and-death weather data for commanders and troops with limousine-sized satellites. Smaller is in for this next generation, and privately operated constellations could play a prominent role too. Debra Werner went looking for what could come after the Defense Meteorological Satellite Program.

BY DEBRA WERNER | werner.debra@gmail.com

The U.S. Air Force launched the DMSP-19 polar-orbiting satellite in 2014, confident that it would stream temperature and humidity data well beyond its planned five-year-minimum lifespan. Most of the satellite's predecessors in the Defense Meteorological Satellite Program had exceeded their design lives since the 1970s. If anything did go wrong, the Air Force had a backup, DMSP-20, in storage and ready for launching in a pinch.

These polar orbiters are especially important to the far-flung U.S. military, because they amass global coverage twice a day as they circle from pole to pole. They also deliver finer resolution imagery and data than is possible from geosynchronous satellites orbiting thousands of kilometers in space, and they watch the high latitudes that those geosynchronous satellites cannot see. From this and civilian data, the Air Force creates forecasts for the Army and its own forces, while sharing DMSP data with the Navy, which has its own forecasters.

Enter Congress, where lawmakers knew that the Air Force would sooner or later be requesting hundreds of millions of dollars to replace the DMSP satellites with modern versions. The thinking went: Why sink $40 million a year to keep DMSP-20 and its 1990s-era technology in climate-controlled storage? Congress zeroed funding for DMSP in 2016, including the storage plan, and the legislation instructed the Air Force to shut down the program.

It only took a few months for things to go terribly wrong. DMSP-19 stopped responding to operators due to a power failure within its command and control system. The Air Force rejected the idea of going back to Congress to request funding to launch DMSP-20, because some officials feared that the satellite might experience the same kind of power failure. Today, DMSP-20 is a museum piece, and the U.S. military is left to rely on DMSP-17 launched in 2006 and DMSP-18 launched in 2009.

The loss of DMSP-19 injected a sense of urgency into deliberations over what should come after the DMSP constellation, and it underscored the risk of relying so heavily on the fate of a single satellite. Instead of buying modern versions of the limousine-sized DMSP satellites, the Air Force will disaggregate the next weather sensors onto a handful of smaller satellites. These satellites won't meet all of the military's weather needs, so the Air Force is weighing a role for commercially operated weather satellites, plus the help of allies, as always.

Unlike NOAA, which spends billions of dollars annually on weather satellites, the Air Force plans to spend just under $800 million to $1 billion over five years on these new weather satellites and sensors.

Being realistic

As important as the DMSP satellites have been, they have never been the whole forecasting story for the U.S. military. Much of the time, the military is happy to rely on data from NOAA satellites and those operated by U.S. allies. But when special operators are preparing to come ashore under cover of night, for instance, they need exceptional detail about tides and atmospheric conditions, and they need the information to come through a secure network that won't break down even momentarily.

"The National Weather Service has great stuff, but they are not built for wartime," says retired Adm. David Titley, who was the Navy's top oceanographer and later NOAA's chief operating officer. The bottom line is "the Department of Defense weather capability absolutely, positively has to work when somebody is shooting at you."

If money were not an issue, the Defense Department would run an entire weather forecasting apparatus, from sensors in orbit to networks to move the data around. "But we have to be realistic," says Ralph Stoffler, the Air Force director of weather and deputy chief of staff for operations, who oversees weather policies, plans and programs for the Army and Air Force. The Naval Meteorology and Oceanography Command at Stennis Space Center in Mississippi performs a similar role for the Navy.

"A combination of a core capability that DoD owns with leveraging access to information provided by key allies and coalition partners is the way DoD is meeting its needs of assurance to the data and reducing costs at the same time," Stoffler says.

"THE NATIONAL WEATHER SERVICE HAS GREAT STUFF, BUT THEY ARE NOT BUILT FOR WARTIME." THE BOTTOM LINE IS "THE DEPARTMENT OF DEFENSE WEATHER CAPABILITY ABSOLUTELY, POSITIVELY HAS TO WORK WHEN SOMEBODY IS SHOOTING AT YOU." — Retired Adm. David Titley

For now, the DMSP constellation remains that core capability. These satellites cross the equator at different locations on each orbit, but always in the early morning on the descending side of their orbits. The satellites gather atmospheric temperature and humidity observations, the fuel for weather models. Forecasters pair this DMSP data with observations from NOAA and Eumetsat, the European Organization for the Exploitation of Meteorological Satellites. Eumetsat satellites cross the equator in the midmorning and NOAA polar orbiters cross the equator in the afternoon. Those three orbits combined supply the vast majority of data for numerical weather models.

With DMSP's end now inevitable, the Defense Department has drafted a two-pronged replacement plan. For the near-term, the Air Force Operationally Responsive Space Office at Kirtland Air Force Base in New Mexico, which changed its name in December to the Space Rapid Capabilities Office, is soliciting bids for a small polar-orbiting satellite. If all goes as planned, the Air Force will spend about $189 million to build, launch and operate this satellite, to be called Operationally Responsive Space-8. It must fill "U.S. Strategic Command's urgent need for Space-Based Environmental Monitoring capability gaps for cloud characterization and theater weather imagery" and "provide weather data support to U.S. Central Command and U.S. Pacific Command," Col. Shahnaz Punjani, Space Rapid Capabilities Office director, said in a written response to questions.

ORS-8 would be a stopgap, a low-cost experimental satellite without extensive backup systems to keep it working for many years. Longer term, the Air Force is planning to buy two kinds of satellites. Ball Aerospace is developing Weather System Follow-on Microwave, a satellite to monitor ocean wind speed and direction, tropical cyclone intensity and energetic charged particles under a $93.7 million contract awarded in November 2017. The fixed-price contract includes options for two low Earth orbit satellites.

Plans are also in the works to buy at least one imaging satellite that would observe clouds and monitor weather around the world for at least five years. With an estimated $450 million on the line, companies are jockeying for position ahead of the competition to build a single Weather System Follow-on Electro Optical Infrared satellite, although the contract may include an option for a second satellite, according to the request for information published last November.

For WSF-E, Harris Corp. thinks an updated version of its Advanced Very High Resolution Radiometer would be the best choice for its sensor. When the Air Force was looking for technologies for future weather satellites in 2013, it gave Harris $12.7 million to update the design of AVHRR, a cross-track scanner that has flown on 19 NOAA Polar Orbiting Environmental Satellites since 1978. The updated version, called the Enhanced AVHRR, would reveal cloud cover and monitor temperature. It would do this by measuring heat reflected by Earth's surface, bodies of water and cloud tops with a 20-centimeter telescope that scans from horizon to horizon, measuring visible near infrared and thermal infrared energy across nine channels covering wavelengths from 0.5 to 11.8 micrometers. The result would be imagery with 1-kilometer resolution. The sensor's onboard passive radiant cooler must keep the thermal infrared detectors at 105 degrees Kelvin. In flight,

▲ **The U.S. Air Force** plans to put weather sensors on a group of smaller satellites rather than buy modern versions of the Defense Meteorological Satellite Program satellites, above.

Lockheed Martin

Enhanced AVHRR would calibrate itself with a warm calibration target onboard and a view of deep space.

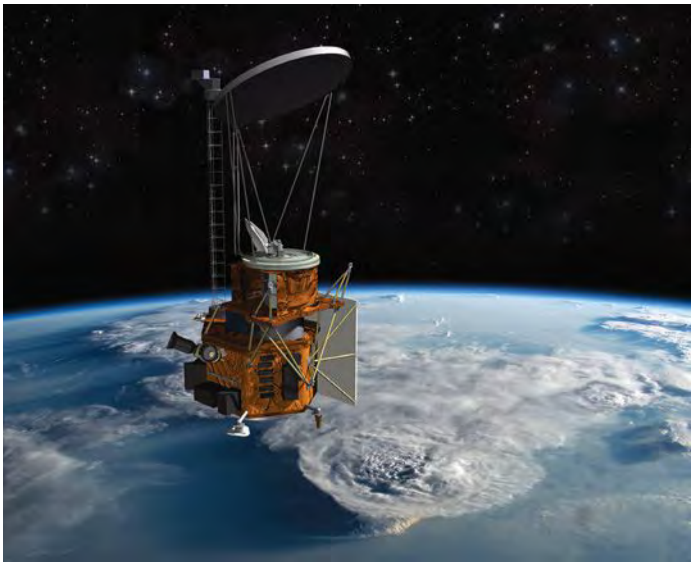
"It's affordable, small and flexible," says Eric Webster, Harris Environmental Solutions vice president for business development. Since AVHRR is roughly the size of a roll-on suitcase, the Air Force could fly it alone on a small military satellite or send it into orbit as a hosted payload on a commercial satellite, Webster says.

Raytheon thinks its Visible Infrared Imaging Radiometer Suite, or VIIRS (pronounced VEERZ), first flown on the NASA-NOAA Polar orbiting Partnership satellite in 2011, would be a better choice. VIIRS gathers sea, land and atmospheric imagery and data with a rotating telescope that captures light from Earth in 22 spectral bands. Other optics then direct the light into the sensor's aft optics assembly and through a beam-splitter, which sends visible and infrared wavelengths to four focal planes cooled to cryogenic temperatures to ensure sensitivity.

VIIRS was conceived as part of the National Polar-orbiting Operational Environmental Satellite System, or NPOESS, program, a failed effort to develop a single constellation of polar orbiters for military and civilian forecasters. NPOESS was started in 1994 by the Clinton administration and backed by Congress as a plan to save money. Instead, costs spiraled out of control due to the complexity and sheer number of instruments on each satellite, prompting the Obama administration to cancel NPOESS in 2010.

From its start in NPOESS, VIIRS was focused on meeting NASA, NOAA and Defense Department requirements. VIIRS is particularly useful for military operations because it can reveal fog over the ocean, pinpoint ships traveling at night and show airborne dust against a desert backdrop, says Shawn Cochran, acting chief scientist for Raytheon's Joint Polar Satellite System Common Ground System. The Joint Polar Satellite System is a constellation established after the collapse of NPOESS. The Defense Department already receives VIIRS data from the NASA-NOAA Suomi NPP satellite and

Measuring ocean winds



The U.S. military sees a special need to predict wind speed and direction, given the impact those factors can have on vessels, aircraft and other mission-critical factors.

Under a contract awarded by the U.S. Air Force last November, Ball Aerospace of Colorado aims to prove that the company can provide the wind capability affordably by adapting satellite technologies flown on civilian spacecraft.

If Ball gets the greenlight to start fabrication, it will deliver up to two Weather System Follow-on-Microwave, or WSF-M, satellites, including a wind-sensing microwave instrument for each and installation of a charged particle sensor supplied by the Air Force as a hosted payload for each. The total award if the Air Force exercises options for two satellites is $457.9 million.

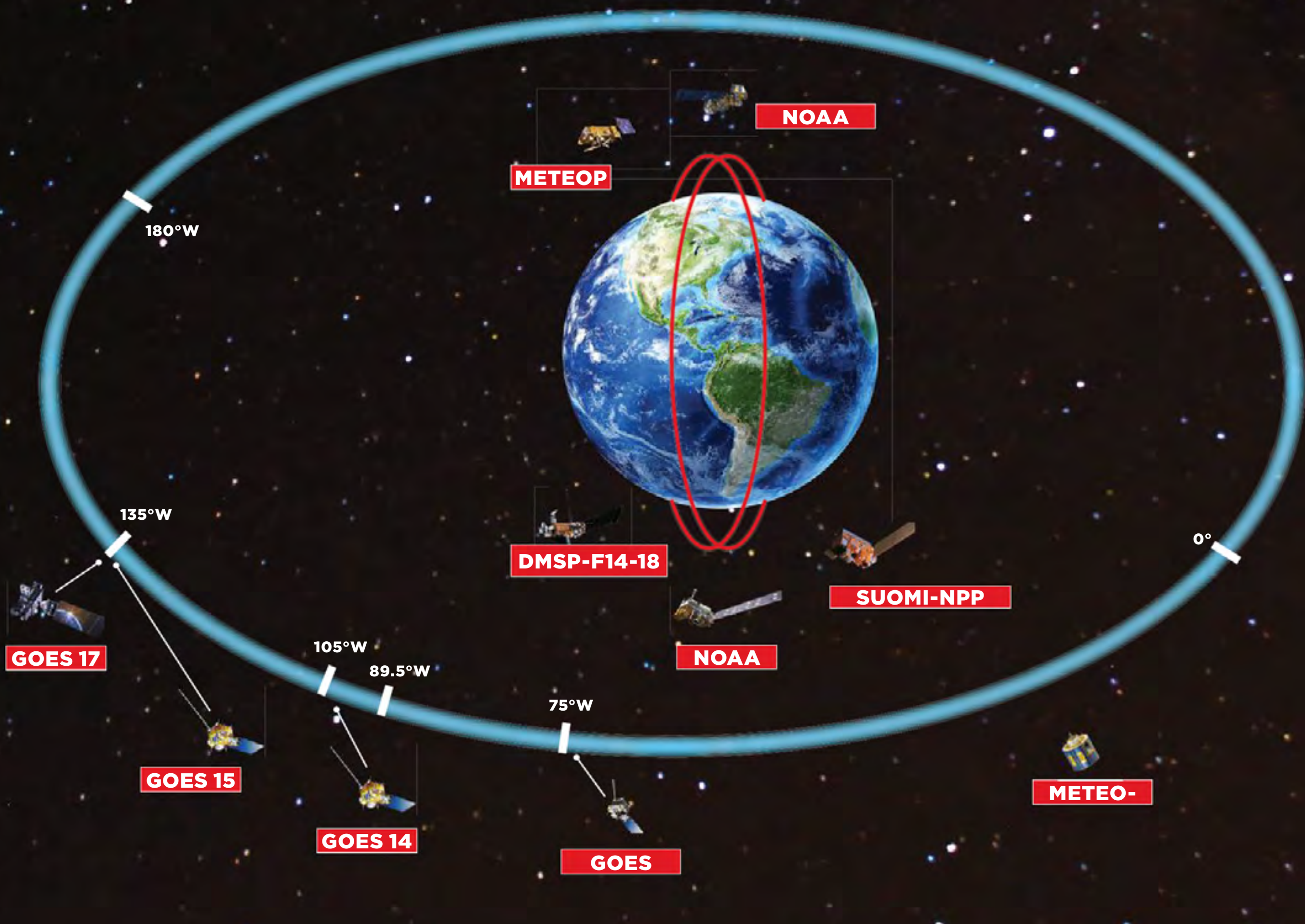
Ball plans to customize each satellite on the Ball Configurable Platform, the company's standardized design for a satellite frame or bus. This design also forms the core of the NASA-NOAA Suomi National Polar-orbiting Partnership satellite launched in 2011 and the NOAA-20 weather satellite (formerly Joint Polar Satellite System-1) launched in November.

The Microwave Imagers will be modified versions of the Global Precipitation Measurement Microwave Imager, or GMI, which rides on a NASA-JAXA (Japan Aerospace Exploration Agency) satellite launched in 2014.

For the military application, Ball is enlarging GMI's rapidly rotating main reflector by about 50 percent. Making this flat antenna larger will improve its spatial resolution. Ball also is eliminating two higher-frequency channels and adding digital polarimetric receivers to three channels. These receivers pick up microwaves in two orientations, the vertical and horizontal. "It's like putting on a pair of polarized sunglasses," says Ball's Cory Springer, director for weather and environment. With that information, meteorologists can derive wind speed and direction. With the two instruments, WSF-M will measure ocean surface winds, tropical cyclone intensity and energetic charged particles that can interfere with environmental sensors. In addition, WSF-M will offer the Air Force a backup method for observing sea ice and measuring, for example, how thick it is, a task currently performed by the Air Force's Defense Meteorological Satellite Program satellites. — Debra Werner

Weather data flows from allies' satellites

The U.S. Defense Department relies on its Defense Meteorological Satellite Program satellites and data from allies for its weather forecasts.



Sources: NOAA, European Space Agency, Eumetsat

NOAA-20 launched in November 2017. If the military wants VIIRS to fly in its preferred early morning orbit, it could buy the instrument from Raytheon's hot production line, says Wallis Laughrey, Raytheon Space Systems vice president.

Dealing with a gap

There is a risk that the remaining DMSP satellites could fail before anything new flies, since the youngest one is nearly 9 years old. "If all goes well, ORS-8 will launch in time," says Stoffler, the retired Air Force colonel who oversees weather matters for the Army and Air Force. "If ORS-8 doesn't come online when we expect it to, there could be a gap that we have to deal with. One of the ways of dealing with that gap is commercial data."

"While the military may continue to build and control some weather satellites for security reasons, much lower-cost weather data from the commercial sector could be cost-effective for the majority of weather forecasting needs."

— retired Navy Adm. Conrad Lautenbacher, former NOAA administrator who leads GeoOptics

So, the Air Force is investigating a role for commercial satellites in plugging the gap. A handful of U.S. companies, including Spire of San Francisco, Planet-IQ of Colorado, and GeoOptics of California, are building small satellites with a variety of sensors to gather weather data for the Air Force, NOAA and commercial customers. Spire, alone, has launched hundreds of the radio occultation nanosatellites. These monitor temperature and water vapor by measuring how the atmosphere refracts transmissions from GPS satellites as they pass behind Earth from the vantage point of the spacecraft, the technique proved by 70-kilogram satellites in the U.S.-Taiwanese COSMIC constellation launched in 2006. COSMIC stands for Constellation Observing System for Meteorology Ionosphere and Climate.

"The more complex and larger the satellite, the longer it takes to design, build, and launch," says retired Navy Adm. Conrad Lautenbacher, a former NOAA administrator who leads GeoOptics. "While certainly the military may continue to build and control some weather satellites for security reasons, much lower-cost commercial weather data from the commercial sector could be cost-effective for the majority of weather forecasting needs."

Congress is encouraging the Defense Department to test the idea that commercial weather sensors could supply data at a fraction of the cost of military satellites. In 2017 and 2018, Congress gave the Defense Department money to start buying commercial weather data to assess its impact on weather models. That trial runs until October but Stoffler already sees promise in miniature satellites and commercial data sources.

"One of the things we've been trying to do, frankly, is get away from large satellites," he says. "As you saw with DMSP-19, if one small component fails, you lose access to that particular satellite, which means all seven sensors are lost immediately. As we go down the path of microsatellites, cubesats and disaggregation, we'll be able to maintain a good secure constellation and replacing individual satellites should be considerably less expensive." ★

DMSP-20

The Defense Meteorological Satellite Program-20 satellite is on display at the U.S. Air Force Space and Missile Systems Center at Los Angeles Air Force Base.

U.S. weighs solutions for geosynchronous gap

IN A COUPLE OF YEARS, the U.S. military will face another hole in its weather satellite coverage, with no American or allied satellites in geostationary orbit over the U.S. Central Command area of responsibility, which spans from the Middle East to Central and South Asia, including Iraq and Afghanistan. U.S. civil geostationary satellites focus primarily on the continental United States and surrounding oceans. Europe, which has been operating satellites over the Middle East and sharing data with the U.S. military, plans to stop covering the region when its current satellite Meteosat 8 runs out of fuel in late 2020 or early 2021.

At that point, the United Nations' World Meteorological Organization will turn to Russian and Chinese geostationary weather satellites for information. That's not an option for the Defense Department. Congress directed the Defense Department in a report accompanying the 2016 National Defense Authorization Act not to rely on Russian or Chinese weather satellite data, which military experts call a no-brainer.

"We can't put ourselves in a position of being hostage," says retired U.S. Navy Adm. David Titley, a professor of meteorology at Pennsylvania State University and the founding director of its Center for Solutions to Weather and Climate Risk. "It would not be at all surprising if a [Russian or Chinese] satellite had technical difficulties when the Defense Department needed it the most."

Instead, the Pentagon might borrow one of NOAA's backup geostationary weather satellites or look for commercial data sources. "Most of the commercial companies recognize that our area of interest is over the U.S. Central Command area of responsibility," says Ralph Stoffler, the Air Force director of weather and deputy chief of staff for operations, who oversees weather policies, plans and programs for the Army and Air Force. "I believe even if we have a perceived gap, the commercial viability will help us cover that."

— Debra Werner