NEXT-GENERATION SEARCH AND RESCUE

Managers of the international, satellite-aided search-and-rescue network have plans to make it faster and more accurate, knowing that they must do so without jeopardizing the service's famous reliability. Meanwhile, a host of separate commercial SAR services are on the rise, welcomed by consumers for their 21st Century features, but greeted with words of caution by some experts. Jan Tegler looks at the interplay between commercial and government SAR.

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Fifty kilometers east of Fort Lauderdale, Florida, and motoring through unremarkable seas toward Bimini for a New Year's celebration, Chris Hanna had the sickening feeling that he had just "run over something in the middle of the ocean."

Hanna's mate told him he had lost one of the three outboard engines powering the 11-meter vessel. Scanning his gauges, Hanna was momentarily baffled. The engines were running at near full revolutions per minute.

"No!" the mate said, "you lost the actual engine. It's gone!"

Hanna snapped his head around and saw his starboard engine trailing off the right side, connected only by its rigging, and still roaring its 300 horsepower.

He shut down, and the outboard snapped its rigging and sank. When Hanna tried to start the remaining engines, "nothing but alarms went off." A late December family trip to the Bahamian island had gone terribly wrong.

Hanna knew it was time to seek help via satellite.

Not so many years ago, the only way to do that would have been through Cospas-SARSAT, the international search-and-rescue network that in 1985 was declared operational by the governments of Canada, the U.S. and the Soviet Union. Cospas is shorthand for the Russian words for System for the Search of Vessels in Distress; SARSAT stands for Search and Rescue Satellite Aided Tracking. Trigger a distress signal, and this network locates you in minutes with an accuracy of kilometers.

These days, boaters like Hanna, not to mention adventurers and international shipping companies, can also choose from an array of commercial satellite-aided search-and-rescue devices and services. Functions can include GPS forwarding, texting, voice communications and automated acknowledgments, all operating separately from the internationally protected 406 MHz distress frequency for Cospas-SARSAT, a network that is undergoing its own improvements too.

This consumer trend, while welcomed by many, also earns words of caution from some government SAR managers.

"If you're near death, you're going to want 99.9 percent reliability" of a unit certified to communicate over the 406 MHz frequency, says NASA's Lisa Mazzuca, who manages a team of engineers in the SAR Office of NASA's Goddard Space Flight Center in Maryland. Her team develops prototype components whose designs are reviewed internationally and turned into specifications for commercially manufactured Cospas-SARSAT distress emitters, called beacons. Her team also designs the SAR packages

▼ **Chris Hanna** was piloting a boat similar to this Everglades Center Console when he lost engine power and had to activate emergency beacons.

Everglades

NASA

▲ **Devices such** as Emergency Position Indicating Radio Beacons and Personal Locator Beacons broadcast signals at 406 MHz that are relayed to emergency centers whose staff notify responders.

on NOAA weather satellites and Air Force GPS satellites, plus the ground receivers that analyze the distress signals to find the source of transmission.

The overarching message from Mazzuca and others: Don't buy a non-406 MHz device in the belief that you have the same level of reliability as provided by the government SAR network overhead.

Call for help

Consider Hanna's emergency. The first thing he did was activate two devices certified to transmit 406 MHz signals to the Cospas-SARSAT network. One was a hand-held Personal Locator Beacon and the other was a slightly larger device, called an EPIRB, short for Emergency Position Indicating Radio Beacon. Passenger planes carry a third kind of device called an Emergency Locator Transmitter.

Hanna's distress signals triggered a sequence of actions that has saved 43,000 people globally and 8,400 in the U.S., according to data from NOAA.

The devices radiated homing signals locally for first responders and also sent bursts of signals radiating into space. If all went typically, and there's no reason to believe things did not, these signals were detected by a SAR package on NOAA's GOES-East weather satellite and, most importantly, by one of the five SAR-equipped government weather satellites operated by NOAA and Eumetsat, the European weather agency. Each carries a receiver-transmitter known as a SARSAT. Once in range of a ground station, a SARSAT repeats the distress signal to a ground receiver along with the time of receipt and a record of its shifting frequency. A second SARSAT narrows the location to within 1 to 2 kilometers at best. Collectively, these satellite packages form a network called LEOSAR, short for Low Earth Orbit Search and Rescue. The U.S. Coast Guard was alerted in Hanna's case, given his proximity to Florida.

What was the cost to Hanna of triggering this elaborate rescue network? Absolutely nothing aside from the price of his EPIRB and PLB devices.

Today's Cospas-SARSAT network gets the job done plenty fast and accurately for most scenarios. Hanna and his passengers were back at a dock in Florida in about six hours. If his boat had been farther from shore, or ablaze or sinking, then precious minutes would have ticked by waiting for that first and second satellite to cross through his distress signals. NOAA and its international partners have a plan to sharpen and speed up Cospas-SARSAT, and add a new function popular in the consumer world: The ability to know your signal has been heard.

Job number one: reliability

Hanna's situation was manageable, but for others, waiting to be rescued can be psychologically agonizing without confirmation that help is on the way. The commercially operated and United Nations-certified Global Maritime Distress and Safety System, an option for nonpolar regions, provides such confirmation. Satellite phones and Globalstar's SPOT emergency messaging devices are popular among boaters and adventurers for that reason too.

Government SAR managers, therefore, are considering a receipt service too, while being mindful that today's EPIRBs, PLBs and Emergency Locator Transmitters must always do two simple functions with nearly flawless reliability: Radiate a distress signal into space and transmit a homing signal for local responders.

Part of that reliability is due to Cospas-SARSAT's dedicated frequency of 406 MHz, which prevents interference. Another part of the reliability comes from keeping Cospas-SARSAT-certified devices relatively simple.

"Most people don't know, even the people selling them, that 'Oh, what do you mean I'm down to an 80 percent reliability that my distress signal will get out?' cautions Mazzuca about the consumer devices operating outside the 406 MHz frequency. As for the Cospas-SARSAT: "We're never going to look like a smartphone. That's for a reason. You will never get 99.9 percent reliability from anything that has a screen on it," she adds.

Consider Hanna's case again. After activating his EPIRB and PLB, he switched on Garmin's In Reach Explorer, a hand-held satellite communicator that produces an SOS signal and enables two-way text messaging via Iridium's constellation of 66 satellites. The device was supposed to allow him to remain in contact with GEOS (pronounced GEE-ohs), a 24/7 commercially operated response center that has a

partnership agreement with Iridium and Globalstar. GEOS confirmed that his SOS signal had been received and passed on to a local rescue coordination center. That was reassuring to Hanna, but then the screen froze and went blank.

Despite cautionary tales, Cospas-SARSAT officials have tentative plans to add Return Link Service to Cospas-SARSAT. Someone in distress would receive an acknowledgment and could categorize the kind of emergency: "If you type in a '1,' that [says] it's a medical injury. If you type '2,' it's a fire," explains Mazzuca.

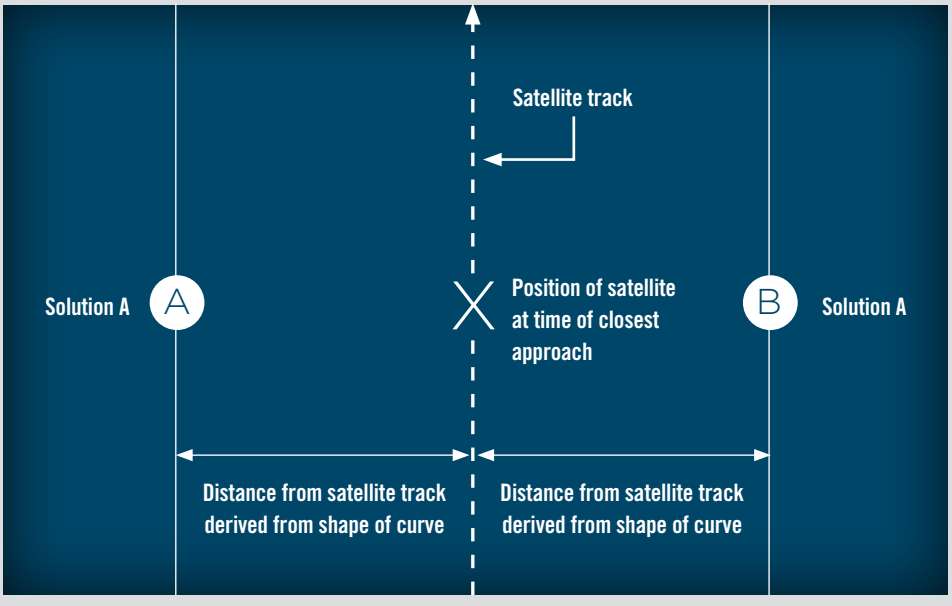
Cospas-SARSAT managers will require lots of testing before including this technology in their internationally approved design specifications for devices.

Then there is the question of why not simply transmit your GPS coordinates to rescuers, given that almost no one leaves home without GPS these days. Globalstar's SPOT devices do this, as do Iridium phones with a push-button SOS function. GPS would avoid the complex Cospas-SARSAT process of parsing location from the shift in the radio frequencies of the distress signals arriving at the SARSAT package. This Doppler shift occurs because the SARSAT is in motion relative to the emitter. As the SARSAT approaches the location of the emitter, it's flying into the radio waves, and so the frequency rises. At the point where the SARSAT makes its closest approach to the emitter, the frequency is all but identical to the frequency emitted by the device. Find that point, and you can find a vessel, person or passengers in distress.

Mazzuca cautions against consumers placing too much reliance on GPS. "There are many areas on the globe where they're 'GPS-starved,' as we say. Then you're getting nothing," she explains. Mountains, for instance, can prevent a GPS device from

Ambiguous position

If you're stranded and sending bursts of distress signals to space from your emergency transmitter, software at a distant ground station will, in an initial step, define two possible locations for you (A and B in the graphic). That's done by identifying the moment when the frequency of the distress signals received by the satellite comes closest to matching the frequency that you're emitting. The frequency varies as the satellite streaks through the radio waves of your signal. A second satellite pass (not shown) is required to narrow the ambiguity to one or two kilometers. NASA, NOAA and their international SAR partners think they can locate people in distress faster by shifting away from this Doppler technique. A new kind of printed circuit board bound for future emergency transmitters, also known as beacons, will transmit stronger signals, more frequently. This time, time to medium Earth orbit. There, MEOSAR packages on multiple U.S. GPS satellites and those of China, Europe and Russia nations will detect the signals for software that will narrow the location on the first burst.



Lisa Mazzuca, NASA
Search and Rescue mission manager, holding the NASA-built prototype Second Generation Beacon, which could revolutionize 406 MHz emergency beacon performance around the world.

Credits: NASA's Goddard Space Flight Center/Bill Hrybyk

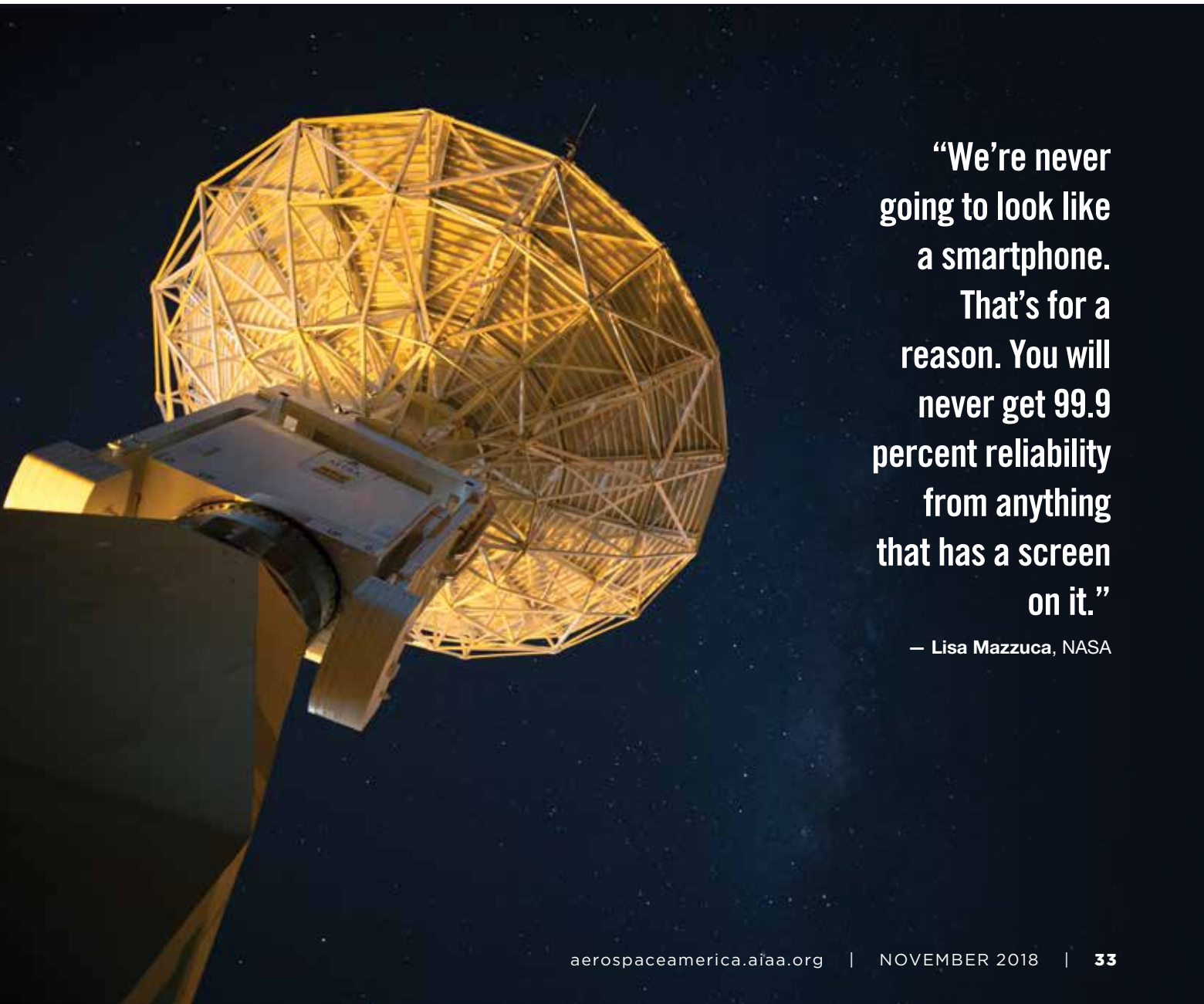
acquiring line-of-sight to enough satellites for an accurate fix. Also, GPS does not cover the full polar regions.

SAR 2.0

Cospas-SARSAT managers have another way in mind to use GPS: Put SAR packages on GPS satellites during manufacturing. Since last December, the U.S. has been testing this network called MEOSAR, short for Medium-altitude Earth-Orbit Search and Rescue. Unlike the LEOSAR satellites, which rise over the horizon and in minutes vanish over the far horizon, multiple MEOSAR packages would always be in line of sight, which is the advantage of medium-altitude orbits. Location would be determined by trilateration, a form of geometry.

Once this system is rolled out more fully, a stranded boater like Hanna would be invisibly guarded by multiple MEOSAR units overhead. The result would be "near instantaneous" distress detection, NASA's Mazzuca says. At the moment, her team is developing a printed circuit board whose design would be incorporated into the specifications for second generation beacons, which would be updated versions of today's EPIRBs, PLBs and ELTs. "What's better with the second generation beacon is that we can produce a latitude-longitude position from the first [distress] signal burst," Mazzuca explains. "That's not possible with current beacons."

The U.S. has been installing a MEOSAR package on each new GPS satellite during assembly, and 19 of them are in orbit so far. The U.S. is not alone in rolling out MEOSAR. Europe has MEOSAR units on 11 of its Galileo navigation satellites. China plans to launch a MEOSAR unit on each of its Beidou satellites, and Russia will do the same with its navigation constellation, GLONASS, a Russian language acronym for Global Navigation Satellite System. All



▼ **An antenna** at Europe's Spaceport in French Guiana transmits and receives signals from Galileo satellites.
European Space Agency

"We're never going to look like a smartphone. That's for a reason. You will never get 99.9 percent reliability from anything that has a screen on it."

— **Lisa Mazzuca**, NASA

Listening for trouble

U.S. and European weather satellites have a side job. They listen for distress signals from ships, aircraft and individuals while orbiting from pole to pole. This is done with packages of electronics called SARSATs, which together form the Low Earth Orbit Search and Rescue, or LEOSAR, network. Here are the five operational SARSATs and the satellites the carry them:

INSTRUMENT	SATELLITE	LAUNCH DATE
SARSAT-7 Canada, France	NOAA-15 United States	May 1998
SARSAT-10 Canada, France	NOAA-18 United States	May 2005
SARSAT-11 Canada, France	Metop-A Europe	October 2006
SARSAT-12 Canada, France	NOAA-19 United States	February 2009
SARSAT-13 Canada, France	Metop-B Europe	September 2012

Metop = Meteorological Operational Satellite
SARSAT = Search and Rescue Satellite Aided Tracking

Source: Aerospace America staff research

this activity eventually will bring the total units in space to about 70.

"When you're talking 70-some satellites carrying SAR payloads, the location algorithms will be exceedingly better because you have more data," says NOAA's Allan Knox, a search-and-rescue analyst.

Mazzuca stresses that the transition to full MEOSAR coverage will take patience. "We're only in what we call 'early operational capability' as an international program. It will be a few more years until we have full operational capability with the rest of the world online and we end up with full-Earth coverage.

Redundancy

Some of the most advanced commercial SAR functions today come from the Global Maritime Distress and Safety System, or GMDSS. Since 1999, the London-based satellite operator Inmarsat has been the sole provider of GMDSS, mainly to shipping companies. Inmarsat provides the service via its ring of geostationary communications satellites 36,000 km over the equator. GMDSS has been a good line of business for the company, in that all vessels of 300 gross tons or more must have the service aboard as required by the Safety of Life at Sea Convention. Inmarsat is about to have competition, however, from Iridium of Virginia. In May, the International Maritime Organization certified Iridium to provide GMDSS with its constellation, a service Iridium plans to start in 2020, once amendments to the convention go into effect.

GMDSS has yet to crack the consumer market because of the cost and size of the equipment, but Iridium thinks it might be able to interest boaters, like Hannah, as well as the traditional GMDSS customers, given the number of the functions that its partner, Lars Thrane of Denmark, has packed into the terminal consisting of a handset, display and antenna, for an anticipated price of less than $5,000.

What about the reliability question? Kyle Hurst, a former marine enforcement officer in Australia and now Iridium's director of maritime safety and security services, points out that no boater or captain should rely entirely on one method of calling for help. "Having been at sea, we had multiple systems on the ships I was on. We had the GMDSS. We had EPIRBs. We had flares, VHF radios, HF radios. We had the old distress flags that no one ever uses, he says. "For me, distress communications are all about getting the word out in any way possible, whether it's setting off a beacon, screaming on radios, firing off flares or waving my underpants — whatever means gets the message out."

Hurst thinks government and private-sector SAR have roles to play. "Take the EPIRB, for example. An EPIRB can float free and be activated. If no human

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>
> — **Kyle Hurst**, Iridium

can press a distress alert button and people are in the water, the EPIRB can float free, be activated and send a signal and it will be known that people are in distress. It works the other way as well. If someone can't manage to activate an EPIRB because they can't get to it, but they do manage to press the red button, they can activate a distress alert with GMDSS. As long as there are good standards behind multiple systems, I don't think it matters who runs SARSAT, the government or the private sector."

One drawback of GMDSS, at the moment, is that it's not available on polar routes, given that the coverage footprints of geosynchronous satellites don't reach that far. Iridium's 66 low Earth orbit satellites will, by contrast, provide global coverage. Also, the satellites in the new version of that constellation, called Iridium Next, which is almost fully in place, will carry crosslink antennas to quickly route signals among satellites and to a ground station.

Hanna did not have GMDSS aboard, and he might not have needed MEOSAR, though constant overwatch would be reassuring. An hour after losing his engine he managed to contact a nearby mega-yacht. The yacht made contact with the Coast Guard and confirmed that an HH-65D Dolphin helicopter was on its way. The yacht crew helped guide the helicopter directly to the stricken vessel and remained with it while the HH-65 coordinated with a Coast Guard fast-response cutter, which reached Hanna a half hour later.

The cutter dispatched a small response boat which relieved the yacht and stayed with the powerless powerboat while a Sea Tow vessel made its way toward the scene. With storms brewing, the Coast Guard crew towed Hanna's boat until they made contact with the Sea Tow. The ordeal ended after 5 p.m. local time.

The combination of devices Chris Hanna had on hand aided him in getting a distress alert out. However, he's grateful to the mega-yacht crew who were instrumental in helping the Coast Guard locate his boat, and he's looking forward to better tools for satellite SAR. ★