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ENHANCE DISASTER PREPARATION AND RESPONSE WITH REMOTE SENSING TECHNOLOGIES

Industry Perspective

ADVANCES IN DATA ANALYSIS, MANAGEMENT AND MACHINE LEARNING ARE IMPROVING DISASTER MANAGEMENT

The recent proliferation of remote sensing platforms has presented those who prepare, respond and help communities recover from natural disasters with unprecedented opportunities and challenges. Accurate, unbiased situational awareness information is available faster than ever. But the enormous volume of raw data is creating new problems related to the timely analysis, extraction and dissemination of useful information. L3Harris has committed to creating product and service solutions that put actionable intelligence into the hands of disaster managers both before and after a catastrophic event occurs.

On the evening of August 4, 2020, a Beirut warehouse filled with ammonium nitrate exploded with enough force to obliterate the entire port facility and damage buildings six miles away. There was an immediate scramble of activity to try and get intelligence as to what happened and what the effects were. Remarkably, just hours later in the dark of night, the European Sentinel-1 satellite captured synthetic aperture radar (SAR) data of the scene providing disaster response officials their first synoptic overview of the destruction.

The Beirut explosion illustrates the value of satellite remote sensing as a critical source of information for disaster management. Since the 1970s and 80s, we have relied on Landsat and SPOT imagery to provide coarse-resolution views of landscapes devastated by disasters like floods, oil spills, tornadoes and wildfires. Most of these data sets, however, were collected days or weeks after the event due to infrequent revisit cycles of the satellites, usually limiting their applications to the clean-up and recovery phase of disaster response.

“Effective disaster response starts before the event occurs – in the planning, preparation and prevention phases...this is where remote sensing and geospatial technologies are increasingly being applied,” said O’Connor.

In the past several years, however, the use of imaging satellites and other geospatial technologies has evolved to support emergency response in the immediate aftermath of a disaster, not weeks later – an enormous leap forward. For response agencies, speed is of the essence, and situational awareness is key. They need to know which areas were hit the hardest so they can deploy search-and-rescue personnel along with water, food and medical aid in a prioritized manner. Remote sensing platforms continue to enhance the kinds of information that can impact mitigation, preparation, response and recovery for all types of disasters.

We are living in a Golden Age of remote sensing where at least one of a plethora of new imaging satellites is likely to pass over a trouble spot within hours of an unplanned event. And more importantly, that satellite will probably be carrying the right sensor for the job. As witnessed in Beirut, Sentinel-1 is equipped with a SAR sensor capable of seeing through darkness and lingering smoke, something an optical satellite could not accomplish.

The transition of geospatial technology from the disaster recovery phase tothe emergency preparation and response phase is a huge achievement, according to Amanda O’Connor, Industry Principal at L3Harris Geospatial. But it’s just part of the story.

NEW TECHNOLOGY: OPPORTUNITIES AND CHALLENGES

While satellites play a glamorous role in this Golden Age, they are accompanied by a supporting cast of manned and unmanned aircraft capturing highly detailed data in localized situations. Airborne sensors have evolved right along with spaceborne devices, collecting diverse data sets faster and more economically than ever before. Even on the ground, land-based sensors, part of the emerging Internet of Things, are enabling better emergency management and response.

The abundance of sensors has been a net positive for disaster planning and situational awareness, but it has also created new challenges related to dealing with all of this data. As sensor platforms have multiplied and their collected data files have become larger and more complex, incident commanders and others in the emergency response chain face at least three distinct challenges:

> Find the right data for a particular situation

> Analyze raw data to extract situational information

> Deliver actionable information to the front lines

Fortunately, L3Harris Geospatial has developed a series of products and services to streamline the querying, retrieval, exploitation and dissemination of actional intelligence for disaster preparation and response.

Several geospatial data collection technologies are the main drivers behind the unprecedented opportunities and challenges facing the disaster management community.

SMALLER SATELLITES

The miniaturization of propulsion, stabilization and power subsystems has reduced the size of satellites to the point where entire constellations can be built and launched for less than the cost of a single legacy platform like Landsat and SPOT. Multi-satellite constellations have become the norm for new commercial Earth observation systems.

The upside to so many satellites in orbit is that nearly every spot on the globe can be imaged several times throughout the day. This means the destruction from an explosion, storm or earthquake can usually be mapped within hours. Even more importantly, multiple satellite passes throughout the day and following days means dynamic ongoing incidents like floods and fires can be tracked continuously.

As noted, the downside is that the enormous volumes of data being captured so quickly from different types of sensors make it difficult to find and analyze the right image for a given situation.

ADVANCED OPTICAL SENSORS

Imaging sensors have gotten smaller, less expensive and more sophisticated allowing them to fly on small satellites, aircraft and drones. While optical sensors by their nature can operate only in daylight, the major technical improvement is spatial resolution, which enables details as small as 30 cm to be seen from space and objects just a few centimeters to be discerned from the sky. Even minor damage to infrastructure and buildings can be mapped accurately in the wake of a disaster – think being able to detect a large rope tethered to a sunken boat. The advantages of higher spatial resolution are infinite, but the downside is enormous files that are difficult to archive and search.

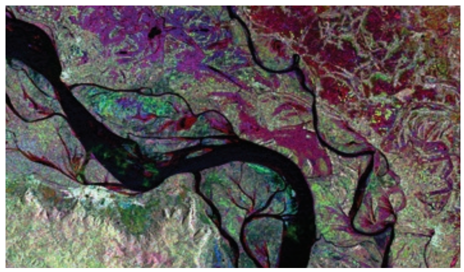
SPECIALTY SENSORS

The two most important specialty sensors being deployed for disaster management today are Hyperspectral and Thermal Infrared scanners.

The wait for commercial hyperspectral sensors has been long, but they are now being flown on satellites, manned space craft like the International Space Station (ISS), aircraft and drones. These passive instruments measure reflected energy typically in 30 or more discrete wavelengths spanning the visible (red, green, blue), near infrared and short-wave infrared. This data contains rich, often invisible insights into objects on the ground, especially vegetation, allowing for subtle differentiation by type or condition.

In disaster management, hyperspectral imagery is now being used to classify land cover vegetation in areas prone to wildfires. Some species burn more readily than others, and this helps planners map sites requiring mitigation. Additionally, FEMA has begun experimenting with hyperspectral data to classify types of post-storm debris piles to facilitate clean-up efforts. The main challenge of this valuable data today is that it is still so new few geospatial professionals have expertise in processing it.

The applications of thermal sensors, mostly flown on manned aircraft and drones, are more straight forward. These optical instruments measure emissions of heat from sources. Today, their most common application is to map hot spots and perimeters of wildfires. A significant advantage is their ability to capture thermal data even through heavy smoke.



SYNTHETIC APERTURE RADAR (SAR)

Unlike passive optical sensors, SAR systems have their own power sources allowing them to capture data day or night, through clouds, light smoke and in most weather conditions. For decades, the power required to operate these systems limited their use to large satellites or aircraft. In just the past two years, technology breakthroughs have put SAR sensors in small satellites – most notably the ICEYE and Capella systems – and in smaller manned aircraft.

Active all-weather imaging makes SAR ideal for capturing disaster information at nighttime, during disasters that cause large amounts of smoke like fires or volcanoes, in cloudy equatorial regions and in polar darkness. Radar also precisely delineates water/land boundaries, providing extremely accurate flood extent mapping. It can also pinpoint oil spills on water. On land, SAR can mitigate geohazards related to ground movement by spotting minute shifts in landform positions and elevations.

The traditional challenge for operational SAR use has been the complexity of the data which historically required expensive and complicated processing software that even the most experienced geospatial professionals were not trained to utilize. The data and tools are now more approachable to the geospatial community.

PROFESSIONAL UAVS

The cost of unmanned aerial vehicles (UAVs), or drones, with the stability and power to carry mapping-grade imaging sensors and laser scanners (LiDAR) has transformed the remote sensing industry. UAVs are now performing imaging and elevation mapping missions over small areas of interest at a cost and speed not possible for manned aircraft.

For disaster applications, they can fly much closer to the surface of objects, getting incredibly detailed views of damage, often from many perspectives. In addition, some drones are so inexpensive they are considered disposable, capturing data in conditions too hazardous for manned aircraft. In terms of disaster mitigation, LiDAR-equipped drones are increasingly being used in powerline corridors to monitor vegetation encroachment that could spark a fire.

The current challenge for UAV use in chaotic situations is the lack of standards for data collection. Multiple drones may be flying over a site simultaneously, each capturing data at a different resolution from a different altitude. Syncing such a variety of data sets for a consistent view of the situation is a major challenge.

Complementing these improvements in data collection are equally critical breakthroughs in data processing and exploitation driven by advances in computer power, automation of image processing algorithms and the integration of Artificial Intelligence into workflows.

MANAGING THE DATA TSUNAMI

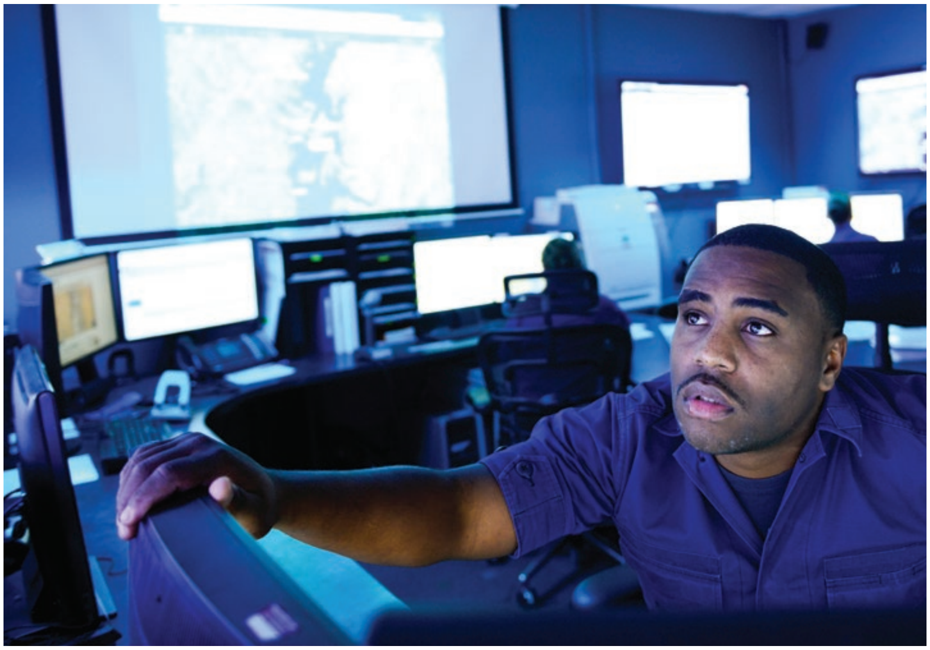
For decades, L3Harris has developed solutions for the U.S. military, and has been at the front lines of addressing challenges of enormous volumes of raw data coming in too fast for it to be processed, analyzed and digested by commanders. In the last decade, L3Harris has pivoted to customizing many of these same data management remedies as solutions to similar problems facing civilian and private sector organizations.

As noted, the overarching data management problem in chaotic disaster scenarios is finding the right data set, processing it into understandable information and disseminating that information to responders in the field.

To accomplish data query and information delivery, L3Harris Geospatial offers Jagwire™, a web-based software product providing an end-to-end geospatial data management solution and delivering near real-time search and discovery, image exploitation and information dissemination. Jagwire is capable of ingesting enormous volumes of incoming geospatial data, including live video feeds, satellite imagery, LiDAR point clouds and GIS vector layers.

"Jagwire is designed to deliver imagery and other geospatial files so they are understandable to personnel with no GIS or image processing training," said Joey Griebel, L3Harris North American Sales Manager. "Even different types of video or imagery streamed in real time from a UAV can be presented as a common operating picture to many incident commanders at different locations."

During multiple California wildfires in the summer of 2020, L3Harris supported fire perimeter mapping activities. Throughout the disasters, the CA Air National Guard flew drones equipped with thermal infrared video cameras. These video feeds were downlinked to a third-party processing hub on the ground that applied AI algorithms to extract wildfire perimeters from the thermal infrared data. In seconds, this information was transmitted to Jagwire, which streamed the annotated videos to mobile devices in the field and laptop computers in other incident command centers.



SIMPLIFYING INFORMATION EXTRACTION

Data management is critical, but it is only the first step in dealing with the torrent of incoming geospatial data. The next step is extracting meaningful information from the wide variety of complex data sets now available.

L3Harris offers an information extraction solution in the form of its commercially available ENVI® software. ENVI is a robust geospatial data analysis software that allows anyone with minimal training to extract meaningful information from all types of imagery – optical, multispectral, hyperspectral, thermal, LiDAR and SAR.

"ENVI users don't have to be remote sensing scientists or big data analysis experts to derive meaningful information from raw data sets," said O'Connor.

L3Harris has developed science-based image analysis algorithms and integrated them into automated workflows in ENVI. This enables users to derive answers to the most complicated geospatial queries from enormous data sets with a few clicks of the mouse. Moreover, ENVI gives more experienced users the means to create algorithms and build customized automated analysis processes of their own via creating visual models or coding.

To facilitate certain image analysis applications, ENVI bundles complex workflows into more than 200 automated modules or tools (often called 'Tasks'). These span many functional areas including georeferencing, calibration, spectral analysis, morphological filters, classification, object detection, terrain modeling, point cloud analysis, SAR analysis, time series operations, machine learning / deep learning and many more.

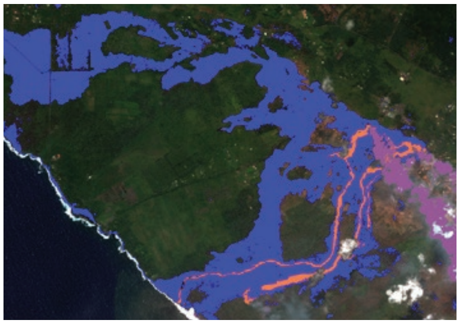
Change detection is among the disaster manager's most powerful tools. Images acquired over the same area before and after an event are loaded into ENVI, and with the push of a few buttons, the software identifies where change – or damage – has occurred over time.

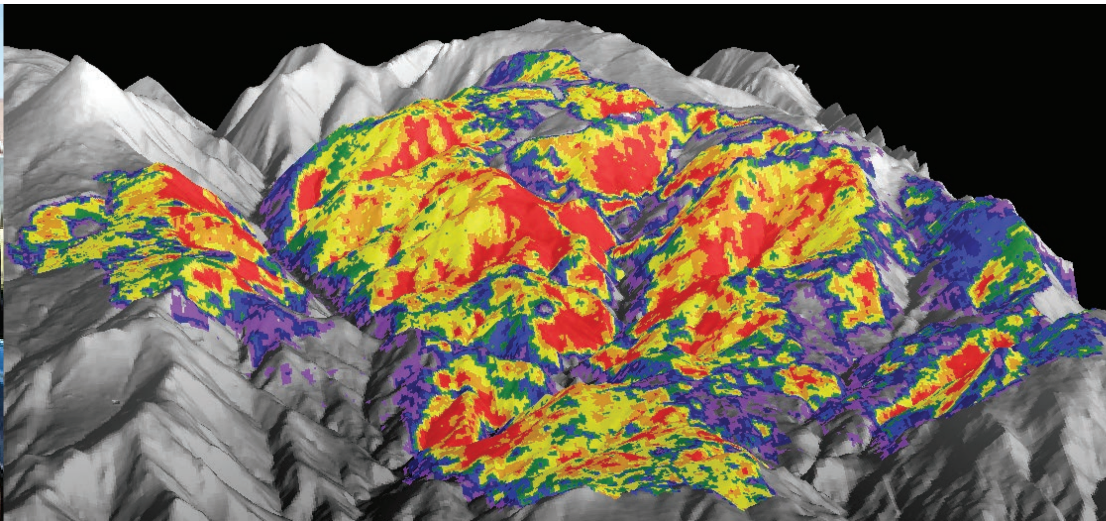
The ENVI Feature Extraction module puts the power of the computer to work identifying features based on their spatial, spectral and textural characteristics. Rivers, lakes, fields, trees and coastlines can automatically be mapped.

ENVI feature extraction algorithms have become so sophisticated, they can even differentiate objects by their condition in multispectral imagery. For example, stressed plants can be isolated automatically from healthy ones in farm fields or forests. This information is used to find and remediate disease or infestation before they expand into widespread crop failures which can wreak havoc on food security and economic stability.

ENVI Modeler is frequently used in disaster preparation to set up complex information extraction workflows to be performed repeatedly in an automated fashion as new imagery is collected and received. The workflow, for example, could continuously monitor vegetative class changes like grasses to shrubbery in hyperspectral imagery and trigger a warning when certain dangerous thresholds are exceeded.

In addition, ENVI is easily extendable via its scripting language, IDL®. This enables ENVI users to create customized algorithms, workflows and analytics that suit their needs. For example, NASA technicians used IDL to create 3D visualizations of rain and snowfall data captured by its Global Precipitation Measurement (GPM) mission. GPM gathers precipitation data from several satellites carrying radar instruments for use in a variety of applications. Among the most important is modeling precipitation volumes in near real time as a predictor of dangerous flooding and related rainfall events.





AUTOMATING ANALYTICS WITH DEEP LEARNING

The identification of specific objects in data sets has been greatly facilitated by automated recognition with the ENVI FX module. There are numerous other features specific to identifying the destruction and damage such as spectral, textural and special qualities related to various catastrophes that disaster managers need to find and map in remotely sensed data sets.

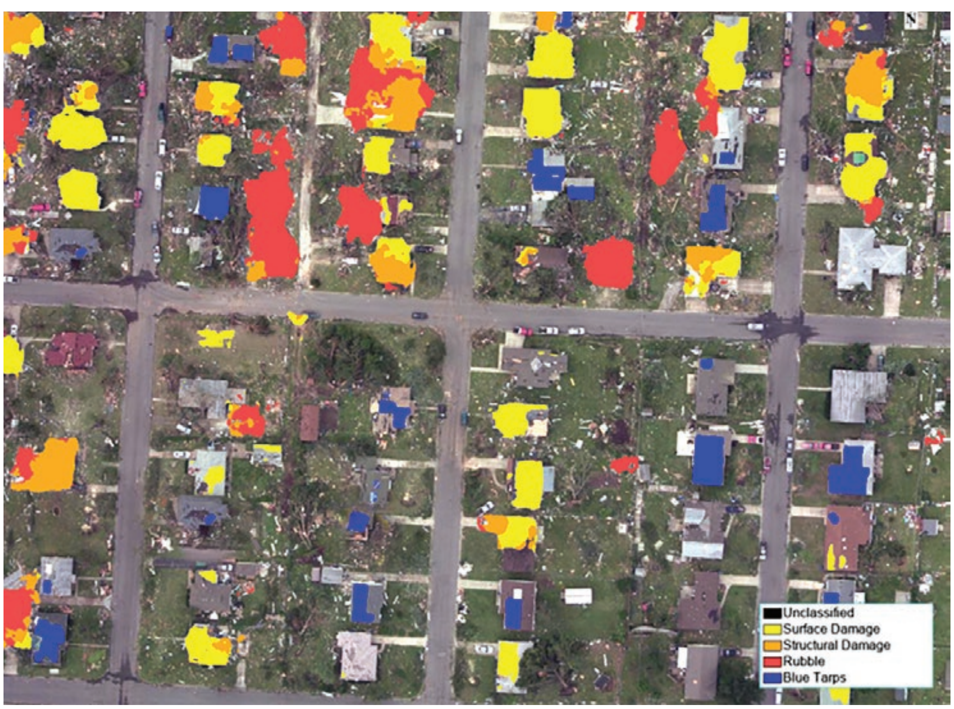
L3Harris has a solution for this challenge as well – ENVI Deep Learning. A form of Artificial Intelligence, Deep Learning, enables the user to 'teach' the software how to recognize nearly any feature or condition in the data by its spectral, situational and neighboring features. Where earlier forms of Machine Learning algorithms required the user to 'show' the computer hundreds of examples of the feature to be identified, Deep Learning uses iterative algorithms that can learn from just a dozen examples in some cases.

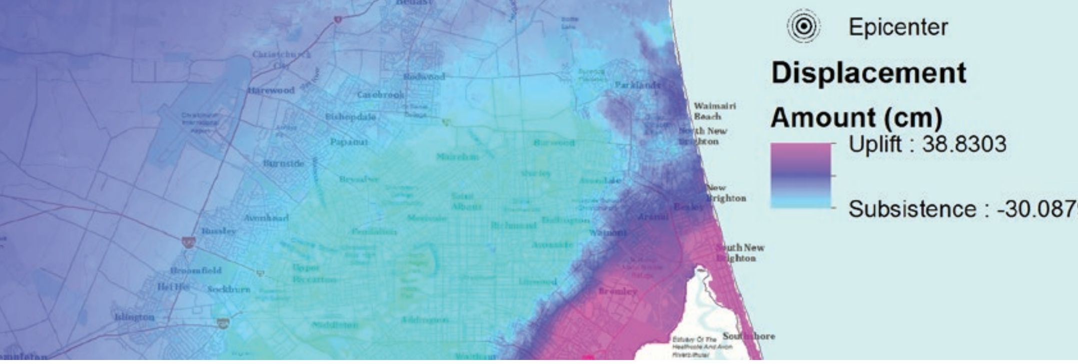
"As with the other ENVI modules, you don't have to be an Artificial Intelligence expert or programmer to use the ENVI Deep Learning module," said Griebel. "The module has intuitive tools and workflows that enable users to easily label data and generate models with the click of a button."

Disaster planners have embraced the ENVI Deep Learning module for the significant savings in time it provides them, compared with manual processes.

"Finding and counting all the damaged houses, and differentiating them from rubble piles, in the imagery would have taken days with the naked eye" said Griebel.

In the aftermath of a March 2020 tornado that tore through a suburb of Nashville, Tenn., L3Harris obtained aerial imagery collected after the deadly incident. The image resolution was sufficient to clearly identify damage to homes and other structures. In less than two hours, a technician used the ENVI Deep Learning module to teach the computer to find damaged structures on its own. The actual mapping of destruction in the imagery took just a few minutes. "Finding and counting all the damaged houses, and differentiating them from rubble piles, in the imagery would have taken days with the naked eye," said Griebel.





EXTRACTING INFORMATION FROM RADAR AND HYPERSPECTRAL DATA

Image data sets are becoming more complex, and SAR and Hyperspectral are the two leading examples. Their size makes them particularly difficult to automate and exploit. Again, L3Harris has leveraged the analytical capabilities in ENVI to automate the information extraction functions from these two data sets.

To make exploiting SAR data more user friendly, L3Harris has introduced ENVI SARscape® Analytics, an analysis module that integrates multiple processing functions and algorithms into simplified, automated workflows. As with the other ENVI modules, ENVI SARscape puts powerful scientific capabilities into the hands of end users to quickly and easily extract meaningful results from SAR data sets.

In the Beirut port explosion cited earlier, L3Harris technicians used ENVI SARscape Analytics to process the Sentinel-1 satellite SAR data and then overlay it on an archived optical image of the same area to perform a change detection analysis. The result was a detailed map highlighting any feature that had been altered by the blast, including structural damage or covering by debris.

Read the full Beirut case study >

With hyperspectral imagery more readily available thanks to new sources of data (Satellites, ISS hosted systems, aerial and drone systems), disaster planners and managers have greater access to the rich information that they contain. L3Harris Geospatial has continued its tradition of creating simplified push button workflows for hyperspectral data sets.

The most popular spectral workflows are:

> Anomaly Detection

> Atmospheric Correction

> Change Detection

L3Harris Geospatial applied deep learning technology to airborne images captured over Nashville, Tennessee, following a deadly March 2020 tornado. Using the ENVI Deep Learning module, which is offered as an extension to ENVI geospatial analysis software, technicians identified where building damage had been inflicted by the tornado and charted its precise path of destruction from the aerial photos – in less than two hours.

TAPPING THE INTERNET OF THINGS (IOT)

Not all remote sensing devices fly on satellites and aircraft. Data-gathering sensors are all around us, and efforts are being made to federate these ground observing sensors for the good of society.

One of the areas where L3Harris has made a valuable impact is in hyper-local weather monitoring. Despite billions spent on Doppler radar and satellite assets, meteorologists still struggle to gain insights into weather conditions that occur on a hyper-local scale and in real-time. Ground-based sensors can deliver complimentary information in context not before considered especially to drivers on the highway and can save lives. Fortunately, an extensive camera sensor array capable of capturing local conditions, already exists in the United States and across the world in the form of existing traffic and surveillance cameras.

L3Harris has tapped into a worldwide set of 50,000 highway CCTVs to develop a ground-level situational awareness system called Helios®, which uses AI technology to monitor the incoming video streams from traffic cameras in real time. Helios algorithms continuously analyze the video from thousands of cameras to detect specific conditions such as precipitation, fog, wet/icy pavement and stopped traffic. The algorithms differentiate between snow, and rain and their intensity.

“Fog kills more people than flooding in Florida,” said Eric Dixon, Helios Product Manager at L3Harris Geospatial. “The state wants to know precisely when and where fog is occurring and heavy rains can be a predictor of flooding, just as snow can precede slick roads,” said Dixon.

Helios, which is offered to state and federal agencies, as well as private companies, as a subscription service, can trigger alerts when certain environmental thresholds are exceeded. Localized heavy rain information can be sent to meteorologists to adjust their forecasts, and transportation agencies can better manage slick roads or stopped traffic. This information, in the context of a driver can be disseminated to the public and directly to drivers in the affected areas. Dangerous conditions detected by Helios can even trigger warnings to be broadcast on highway signs.

“Helios fills the gap in localized weather information that could tell us what is occurring locally during a big storm, which is important information for disaster managers to have,” said Dixon.

MONITORING AND ANALYSIS SERVICES BECOMING POPULAR

While the increase in data variety, volume and revisit frequency of remote sensing devices is a net positive for all consumers of geospatial information, the negative impacts are starting to be felt as well. Specifically, the growing variety of data types and the sheer volume of the massive data sets is creating havoc for some end users. Disaster management professionals simply don’t have time to become subject matter experts on all the different image data sets available to them. And many organizations can’t afford to buy and maintain the computing infrastructure now required to process massive remote sensing data files.

“The majority of our clients are buying ENVI software and doing the work themselves, but there is definitely a pivot toward contracting for services, especially related to ongoing monitoring of specific areas of interest,” said Griebel.

In response, L3Harris has rolled out geospatial solutions services customized to the needs of specific applications. The client does not have to know which type of imagery or analysis algorithms to use. All the client does is describe what disaster management questions need to be answered, and L3Harris takes care of the rest – from choosing the right data set and creating a practical analytical workflow to providing the computer horsepower and formatting the answer in an easy-to-understand format – tailored for disaster managers, first responders and others.

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