Implementing Space Technology and Innovations into Homeland Security and Emergency Management Operations and Activities

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Abstract

Space capabilities, technology, applications, and services represent the forefront of technological development for the homeland security enterprise. Space capabilities and technological innovations are emerging technologies that are shaping and redefining homeland security, emergency management and response operations. These technologies are redefining how we approach emergency operations including damage and risk assessments, information sharing, geospatial intelligence, search and rescue, first responder accountability, tracking, mapping and more. There are numerous expanding uses of space capabilities being developed, tested and implemented to support first responders. NASA's Jet Propulsion Laboratory and DHS Science & Technology Directorate have been working closely to develop innovative solutions based on space technology for use in homeland security & emergency management activities that demonstrate how space technologies have far greater utilization beyond their original spacefaring mission. Finally, this essay explores how space technology is being used in the field today and ways to operationalize these technologies into practice.

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Introduction

Space capabilities and technological innovations are redefining how we approach challenges and activities in homeland security & emergency management. NASA's Jet Propulsion Laboratory and the Department of Homeland Security, Science & Technology Directorate (DHS, S&T) have partnered to develop innovative solutions based on space technology for use in homeland security & emergency management activities. For example, according to testimony before a joint hearing from committees of the U.S. House and Senate,

> satellite imagery and geospatial analysis has enabled FEMA to accurately determine house-to-house damage assessments and expedite millions of dollars of rental assistance to disaster survivors. This capability reduces the cost to the taxpayer as damage assessments can be derived from satellite imagery at a fraction of the cost of ground inspections. In some cases, they are up to 90 percent less costly. A single satellite image can cover hundreds, even thousands of square miles and provide cheaper and timelier data to deployed teams, especially in remote areas.[1]

Interestingly, space technology and satellites are becoming more prominent in homeland security and emergency response activities. The Department of Homeland Security, Science and Technology Directorate in partnership with the U.S. Coast Guard launched two miniature cube-shaped satellites (CubeSats) into space on December 3, 2018, via the SpaceX Falcon 9 rocket to replace an aging satellite;

the new CubeSats will assist with search and rescue missions and monitor maritime traffic in the arctic.[2] It's unique to see that the Department of Homeland Security has ventured into developing space capabilities to support its missions and how these capabilities may further support various activities. A recent study further noted potential uses of satellites and space technology to predict future COVID-19 outbreaks and disease.[3] New space capabilities such as SpaceX's Starlink program can provide high speed internet access globally via a constellation of satellites, which offers great potential to support disaster affected areas.[4] These are but a few recent examples and represent a small fraction of the full range of capabilities and benefits that space technology can provide. The list on figure 1 represents various applications for geographic information system (GIS) technologies to support emergency and disaster management and was compiled from a survey study comprised of international stakeholders.

Hazard Type	Product/Systems	Hazard Type	Products/Systems
Volcano	• Volcanic Activity • Volcanic Topography • Thermal Anomalies Detection for Monitoring Global Volcanism • Sulfur Dioxide Detection • Vegetation Damage Assessment	Flood	• Inundation Map • Damage Assessment Map • Risk Map • Flood Risk Monitoring System • Recovery Process Map
Severe Storm	• Damage Profile • Detection and Forecast • Forest Damage Assessment Map • Infrastructure Damage Assessment Map • Recovery Progress Map	Drought	• Drought Index Map • Drought Index Map for Soil Moisture Monitoring • Drought Index Map for Vegetation Monitoring • Risk Map • Vulnerability Map
Pollution	• Dust Storm Monitoring • Oil Spill Detection • Oil Spill Risk Map • Open Water Pollution Map • Nuclear Radiation Map	Earthquake	• 3D Damage Visualization and Animation • Urban Classification for Risk Analysis • Damage Assessment Map • Reconstruction Monitoring
Mass Movement	• Landslide Hazard Assessment • Landslide Monitoring • Damage Assessment Map	Tsunami	• Damage Assessment Map • Risk Map • Land use Change • Vulnerability Map • Inundation Map • Hazard Map • Reconstruction Monitoring • Early Warning System
Insects	• Locust Habitat Map • Forest and Crop Change Monitoring		
Temperature	• Extreme Heat Risk Map • Cold Wave Map		
Epidemic	• Infectious Disease Risk Map • Infectious Diseases Spread Map • Epidemic Tracking System	Fire	• Risk Map • Burned Area Detection • Detection and Monitoring • Forest Change Monitoring

Figure 1: Longlist of Applicable Geoinformation products and systems. Source: The Value of Geoinformation for Disaster and Risk Management (VALID) | UN-SPIDER Knowledge Portal, 2013.[5]

Space Technology Use in Homeland Security and Emergency Management Activities

Comparative insights into the gaps in U.S. emergency management versus international emergency management demonstrate various ways of incorporating space technology into emergency management practices. The Copernicus Emergency Management Service (CEMS) is perhaps the most robust national emergency management service space agency. It should be considered a national model and a demonstration of how these vital resources, capabilities, applications and services can be operationalized to support emergency and disaster management. As described by the Copernicus website, "The Copernicus Emergency Management Service supports all actors involved in the management of natural or manmade disasters by providing geospatial data and images for informed decision making and constantly monitors Europe and the globe for signals of an impending disaster or evidence of one happening in real time."[6] CEMS demonstrates how space capabilities can be used throughout the disaster management life cycle and to support pre & post disaster activities including long-term recovery. Other notable emergency management space programs include the Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), the Association of Southeast Asian Nations (ASEAN) and respectively China and Russia who each have their own disaster space programs.

Space Capabilities in the United States

In the United States, several key federal agencies possess a number of space capabilities such as the DOD, NRO, NGA, America's Intelligence Agencies, NASA and NOAA that provide: "satellite photoreconnaissance that includes a near real-time capability… This includes providing information for indications and warning and the planning and conduct of military operations; and imaging of the United States and its territories and possessions, consistent with applicable laws, for purposes including, but not limited to, homeland security."[7] The Department of Defense and America's Intelligence agencies have long supported domestic emergency and disaster responses long before 9/11.[8] Post-9/11 U.S. National Space Policy has expanded and further clarified the roles of the Department of Defense and America's Intelligence agencies' support to domestic emergency, disaster and humanitarian response.[9] Mechanisms exist at the federal level to provide space capability support to domestic emergency response activities. However, the federal government is not the only shop in town that can provide space capability support. Over the last decade commercial space capabilities have had a major boom and continue to expand rapidly.

NASA, USGS, FEMA and Other GIS Tools that Can Be Implemented into Activities Today

There are many space capabilities that are available today to support emergency operations. U.S. Geological Survey (USGS) and NASA have partnered to provide various space capabilities and resources for emergency and disaster management use, many of which are publicly available, include web-based applications and are free to use, such as the NASA Earth Science and Earth Data programs. These space applications include near-real time capabilities such as NASA's Fire Information for Resource Management System (FIRMS), "which distributes Near Real-Time (NRT) active fire data within 3 hours of satellite observation from NASA's Moderate Resolution Imaging Spectro-radio-meter (MODIS) and NASA's Visible Infrared Imaging Radiometer Suite (VIIRS)." [10] Additional resources include the Land Processes Distributed Active Archive Center (LP DAAC), which operates as a partnership between USGS & NASA. USGS & NASA also provide various types of educational materials, training, resource lists, webinars and various data products that can be used to support emergency and disaster management activities. For example, NASA provides remote sensing data and applications for disaster management training. According to the NASA website, "NASA remote sensing and modeling resources are useful for managing a variety of disasters - including earthquakes, tsunamis, volcanoes, floods, landslides, wildfires, and oil spills - particularly in regions with very little in situ data." [11] NASA also provides Applied Remote Sensing Training (ARSET). According to the ARSET website, "The (ARSET) program builds the skills to acquire and use NASA satellite and model data for decision support. The program provides training via online webinars and in-person workshops. ARSET trainings are intended for policymakers, NGOs, and other applied science professionals seeking to incorporate NASA remote sensing into their daily activities."[12] NASA ARSET trainings provide "step-by-step instructions for obtaining satellite images, alerts, and crisis management information," and are available in: Air Quality & Health, Disasters, Land, and Water Resources.[13] These are all tools and training that can be implemented today and used to support activities and operations. Figure 2 provides a more comprehensive listing of resources available.

Disasters Tool and Data Portal Reference Sheet	
Worldview	https://worldview.earthdata.nasa.gov
CALIPSO Lidar	https://eosweb.larc.nasa.gov/project/calipso/calipso_table
Global Sulfur Dioxide Monitoring Home Page – NASA Goddard	http://so2.gsfc.nasa.gov
Synthetic Aperture Radar (SAR)	http://uavsar.jpl.nasa.gov
Geodetic Data Exploration (GEOGateway)	http://geo-gateway.org
MISR Images of Tsunami Damage	http://www.misr.jpl.nasa.gov
Global Navigation System Satellites (GNSS)	http://cddis.gsfc.nasa.gov/Techniques/GNSS/GNSS_Overview.html
MODIS Active Fire and Burned Area Products website	http://modis-fire.umd.edu/index.php
Soil Moisture Active/Passive (SMAP)	https://nsidc.org/data/smap
NOAA/NESDIS Volcanic Alert System	www.ospo.noaa.gov/products/atmosphere/vaac http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2

European SACS Volcanic Alert System	http://sacs.aeronomie.be
MISR Plume Height Project 2	https://www.misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes2
The European Support Aviation Control Service (SACS)	http://sacs.aeronomie.be
International Charter Space and Major Disasters Tool	http://cgt.prod.esaportal.eu/chartng
Advanced Rapid Imaging and Analysis (ARIA)	http://aria.jpl.nasa.gov
Short-Term Predication Research and Transition (SPoRT)	http://weather.msfc.nasa.gov/sport
Emergency Data Enhanced Cyber Infrastructure for Disaster Evaluation (E-DECIDER)	http://e-decider.org
Fire Information for Resource Management System (FIRMS)	http://earthdata.nasa.gov/earth-observation-data/near-real-time/firms
VIIRS Active Fire Maps	http://viirsfire.geog.ummd.edu/pages/mapsData
U.S. Forest Service Active Fire Mapping Program	http://activefiremaps.fs.fed.us
MODIS Near Real Time Global Flood Mapping	http://oas.gsfc.nasa.gov/floodmap
Dartmouth Flood Observatory (DFO)	http://floodobservatory.colorado.edu
Extreme Rainfall Detection System – Version 2 (ERDS2)	http://playground.ithacaweb.org/apps/world/leaflet/erds2.html#layers
Global Flood Monitoring System (GFMS)	http://flood.umd.edu
Global Landslide Catalog	http://ojo-streamer.herokuapp.com

Figure 2: Disasters Tool and Data Portal Reference Sheet. Source:
Using NASA Remote Sensing for Disaster Management | ARSET, 2020

The Disasters Tool and Data Portal Reference Sheet is a list of space capabilities available to support emergency and disaster management activities.

FEMA's Geospatial Resource Center

FEMA's GIS Resource Center – which is still under development to note, is designed to support the emergency management community with world-class geospatial information, services, and technologies.[14] FEMA GIS has various tools that provide robust data such as its Hazard Overview, FEMA Geospatial Damage Assessments and Critical Public & Essential Facility Explorer. It contains links to other agency tools such as the CDC's Social Vulnerability Index and is a hub to various resources such as crowdsourced disaster photo mapping to WAZE traffic alerts. Another notable tool is the FEMA Priority Operations Support Tool – POST, which "is a predictive output that displays areas of greatest risk for a given event based on social vulnerability, population, building location and types, and hazard data." [15] Lastly, FEMA GIS has several hubs such as one for Data and Imagery that can provide satellite imagery for listed disasters. These are excellent tools available today for use that can improve data sources available to emergency management programs nationwide.

Disaster Charter

Not that long ago, nations going through disasters or emergencies took what they could get for satellite-sourced imagery. A government might rely on national assets, if available. Or it could turn to the International Charter Space & Major Disasters (Disaster Charter) and ask for assistance to get satellite images of a specific area.

One example of the Disaster Charter at work occurred after Hurricane Maria hit Dominica Island in mid-September 2017.[16] A Russian government-operated earth-observation (EO) satellite took the image on the right after the hurricane had passed through. A Disaster Charter activation tasked the satellite to take that and other pictures. A French Space Agency (CNES)-operated EO satellite collected the image on the left (the "before" picture) in late January 2017. We can't say why they took the picture, but its existence was serendipitous for the Dominican Republic.

Contrasting both images allowed the government to see the magnitude of Maria's path and areas the storm damaged. The Disaster Charter worked, as intended. Note that both pictures were provided by government-operated Earth observation satellites--not unusual for the time.

That same year, commercial company Planet had deployed 146 EO satellites low into the Earth's orbit.[17] The company has deployed more satellites since that time. It runs enough satellites that Planet advertises it can image the entire world every 24 hours, seven days a week.[18] This large constellation means there are potentially more opportunities for satellites to collect images of anywhere on Earth. This change in imagery frequency and availability potentially could benefit a disaster manager--without needing to rely on serendipity.

Planet is not the only company engaging in commercial EO activities. Other startups have entered or are planning to enter the commercial space EO/remote sensing (RS) business. Based on (for most) company press releases, these newest EO/RS operators might contribute five times the existing number of operational EO/RS satellites in the next few years. That's from slightly under the estimated 300 operational EO/RS satellites on-orbit (including government-operated satellites) to an estimated 1,500 EO/RS satellites--mainly commercially-operated.[19]

More satellites will collect more "data" (pictures) of the Earth. More satellites result in more pictures taken more often. And more satellites means there will be a faster response, perhaps with better image resolution, to a disaster/emergency manager's request for an image. Instead of waiting hours, a request may take only minutes to fulfill. Not only that--there will be more types of EO/RS data available.

The new EO/RS operators are not just optical imagery collectors, there are other remote sensing products available: Visible/Multispectral (MS)/Hyperspectral (HS), Infrared, Synthetic Aperture Radar (SAR), and Radio Frequency. Each of these product types only adds to the potential tools an emergency/disaster manager can use. Trying to pinpoint a forest fire hotspot? Then infrared-derived products might be required. Tasked with enforcing the fight against illegal fishing over impossibly large areas? Then maybe a combination of satellite optical imagery and radiofrequency scanning products is useful.

A less obvious result of commercial EO/RS satellite growth is perhaps the possibility for nations to identify areas prone to disasters (fires, earthquakes, hurricanes, etc.) and schedule for updating images before a "season." In other words, the growth of commercial EO/RS satellites also help pin down something more useful for emergency and disaster managers--planning. Their potentially massive data repositories, with scheduled collections, would be a known quantity for emergency/disaster managers to rely upon (and pay those companies to conduct those updates). It is good to know that the data are there to allow emergency/disaster managers to conduct much quicker life-saving and property protection measures when comparing images.

If half of those 1,500 EO/RS satellites are deployed, disaster and emergency managers will have the unique experience of choice. Instead of facing only the bureaucracies inherent with calling on government assets, they can also call on the new commercial EO/RS space operators like Planet, Iceye etc. Those commercial operators are likely to respond more quickly than the average bureaucracy. The Disaster Charter may still be useful and perhaps provide more products in a faster time-frame than before--if these companies join with its members to supply free images whenever disaster strikes (Planet and Iceye have).

The promise of profits is compelling commercial space companies to build out an EO/RS infrastructure, but attaining those profits might take a while. Each one of the companies operating those satellites is bent on somehow making money off of the data their satellites collect. Each company is adding to its EO/RS satellites constellation, in turn creating more image availability. This scenario, which may seem confusing at first based on all of the companies entering this market, can only be good for disaster and emergency managers willing to think ahead.

Challenges with Technology Adaptation in Emergency Management

Emergency Management has long had challenges and even apprehensions about introducing new technologies into its practices. We still see limitations in communications systems, minimal use of web-based information sharing resources, and even some GIS technology often relegated to wildland fires and maybe major floods and hurricane disaster areas. We need to have a better idea of what technology is really out there, who owns it, who can request it and how can it be used more consistently across the industry in a standardized way. Then we need to think about how technology can be added to the classroom to prepare future emergency planners, first responders, and policy makers from the largest metropolitan cities to the smallest towns.

This is reminiscent of the painful growth experience when trying to implement NIMS nationally in 2005. There are still challenges and holdouts in some locales and disciplines when it comes to NIMS adoption even today. This is a challenge that we see just to even get access to the technologies to improve our capabilities across the emergency management arena. The problem then was that we really didn't know what we needed, or even wanted because we didn't really know what was available and we were so used to doing things with traditional tools, new ones just seemed unattainable, especially for small town departments. As an industry, emergency management has not partnered with entities that just might have the next tool we would need. Even today, public service-related education relies heavily on the psychosocial theories, interpersonal interactions, and fundamentals of what our industry is, but we don't use a lot of technology in educating future public servants. The lack of a true standardized set of program objectives in criminal justice and homeland security, i.e., programmatic accreditation, is still an issue in our field. Even looking at the Academy of Criminal Justice Sciences standards for certification there is nothing directly related to technology.

This brings us to emerging space capabilities. For example, it is possible that the Space Force will provide new capabilities that will be useful for emergency management. We know that the space industry has provided us with thousands of technological resources from the electric toothbrush to the cell phone and beyond. Incorporating space technology into emergency management practices presents a leap in technological adaption and innovation that can bring new resources into the homeland security enterprise with the potential to contribute greatly towards solving the myriad of challenges we continue to face.

Recommendations

Space capabilities, applications, services and technologies can provide advanced information, intelligence, data, early warning, tracking and many other leading-edge capabilities to the homeland security enterprise and state and local first responders if awareness, education and training is provided and these products are operationalized nationally for use during all phases of emergency management and response activities. The Department of Homeland Security, Science & Technology Directorate (DHS, S&T) should advocate for the establishment of public-private & academic partnerships across all levels of government and provide substantial new funding to establish a vast repository of case studies on technology adaptation and implementation and to identify best practices and standards. Further grant funding should be provided to make new technologies available nationwide, especially at the state and local level to push the adaptation of new technologies. DHS, S&T should implement funding on a vastly greater scale than its current Civic Innovation Challenge partnership with National Science Foundation and MetroLab. This will provide major progress towards the development of literature that can be used to identify new standards and programs needed to provide these resources nationwide.

Conclusion

Space capabilities have major potential applications for use during all phases of emergencies and disasters. The applications discussed in this essay are just the tip of the iceberg as to the full range of capabilities and technological solutions available. These technologies represent the next great leap in the continuum of technology in the homeland security enterprise. Incorporating space technology into emergency management practices will bring a new generation of tools to facilitate smarter, safer, data-driven responses that will provide quicker, more timely, more accurate data to enable better decision-making and support to frontline first responders.

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Notes

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