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Executive Summary

The National Guard performs a range of missions when natural disasters affect the United States, one of those being incident awareness and assessment (IAA). In this mission, the National Guard employs a range of traditional intelligence, surveillance, and reconnaissance capabilities, as well as analytic capabilities, to provide timely and critical information to local, state, and federal authorities.

The National Guard's responses to a range of recent natural disasters have highlighted the utility of integrating high-resolution commercial satellite imagery (CSI) capabilities into domestic operations to satisfy IAA mission requirements. The National Guard Bureau (NGB) thus asked the Institute for Defense Analyses (IDA) to conduct a survey of current and emerging high-resolution unclassified CSI capabilities and to provide an analysis of how these capabilities could satisfy National Guard IAA mission requirements for responding to natural disasters. The National Guard also asked the IDA team to examine the efficacy of current and potential U.S. Government capabilities for supporting IAA mission requirements in response to natural disasters.

To achieve the project's research objectives, the IDA team reviewed relevant literature and National Guard-supplied data on natural disaster response efforts, and conducted interviews with NGB Intelligence Directorate (J2) staff; Unclassified Processing, Assessment, and Dissemination imagery analysts; the Air Force's Eagle Vision leadership and personnel from the 169th Communications Flight Eagle Vision IV (South Carolina Eagle Vision unit); the U.S. Geological Survey (USGS); the National Geospatial-Intelligence (GEOINT) Agency (NGA); the National Park Service; and four leading Earth observation satellite imagery companies: Airbus Defence and Space, Digital Globe, BlackSky, and Planet. This report documents the IDA team's research; details the findings developed from our literature reviews, interviews, and analyses; and provides conclusions and several recommendations for consideration by the NGB.

The IDA team summarizes its findings below:

- CSI can contribute significantly to satisfying National Guard IAA requirements for natural disasters, including requirements for situational awareness, damage assessment, lines of communication status, evacuation, and search and rescue.
- U.S. Government space imaging assets such as Landsat, ASTER, and the Geostationary Operational Environmental Satellites are intended for scientific

purposes and are not well-suited to address natural disaster relief requirements, primarily due to spatial resolution limitations.

- Panchromatic and multispectral electro-optical sensors with a resolution of 1.0m ground sample distance or better, responsiveness within 24 hours or less, and revisit times of 24 hours or less are required to satisfy most IAA mission needs. Higher resolution and responsiveness may be required for search and rescue, and lower resolution may be acceptable for gaining initial situational awareness. Imagery requirements can vary considerably, however, depending on specific circumstances and applications.
- Synthetic aperture radar (SAR) can be useful in obscured environments such as cloud cover associated with hurricanes or smoke associated with wildfires or volcanic events. SAR does have limitations, however, during certain extreme weather events, such as those that produce strong winds and rain. The National Guard today has limited extant capability to analyze SAR imagery.
- Imagery provided through the National Reconnaissance Office's (NRO) Enhanced View Follow On (EVFO) contract and NGA's Global Enhanced GEOINT Delivery (G-EGD) contract meets most IAA resolution, timeliness, and revisit rate requirements, but the National Guard may only access this imagery for natural disasters that prompt a presidential major disaster or emergency declaration. There are potential opportunities to optimize collection during other natural disaster situations within the scope of the existing contract.
- The business models of leading commercial vendors center largely on providing medium-to-high resolution broad area and global point target collection, with the former tipping and cueing the latter, followed by subsequent analysis of archived imagery and dissemination via a web-based architecture.
  - The combination of broad area coverage and rapid revisit by commercial satellite operators is producing rapidly growing commercial imagery archives that can be used for a wide range of purposes. As a result, companies are increasingly focusing on the development and application of analytic tools that can take advantage of those archives.
  - The commercial vendors interviewed by the IDA team viewed direct downlink primarily as a means to service non-U.S. defense and intelligence customers and maintained that web-based satellite tasking and imagery delivery can fully support unclassified imagery requirements.

The IDA team finds that the NGB has three broad options it could pursue to use CSI to support the IAA mission. These options are not mutually exclusive; rather, the National Guard could choose any combination of these approaches:

1. **Maintain the status quo**. With this option, the National Guard would retain access to CSI from Eagle Vision in all natural disaster situations, access to CSI from DigitalGlobe in the event that the President issues a major disaster or emergency declaration, and access to additional CSI when USGS activates the International Charter.
2. **Seek expanded utilization of the EVFO and G-EGD contracts.** This option would entail the National Guard pursuing ways to gain greater access to the CSI capabilities provided by the existing NRO and NGA contracts with DigitalGlobe, in addition to imagery that becomes available subsequent to a presidential major disaster or emergency declaration.
3. **Establish a separate contract with a vendor for CSI**. With this option, the National Guard would select a specific provider and develop an independent contract for desired CSI capabilities.

IDA's recommendation is that the National Guard pursue the second option: seek to leverage the EVFO and G-EGD contracts to the extent feasible. The National Guard should engage NRO and NGA directly—in collaboration with the Federal Emergency Management Agency, the USGS, the U.S. Forest Service, and other federal organizations responsible for natural disaster relief and imagery support in the United States—to explore the potential for the following steps:

- Developing a concept of operations optimized for standing imagery collection in support of natural disaster response that takes advantage of reduced demand and excess sensor capacity over the continental U.S. and provides commercial vendors wider latitude, when appropriate, to task collections in anticipation of future U.S. Government requirements. This approach could maximize relevant coverage, improve responsiveness, and reduce tasking adjudication delays and complexities, thereby significantly improving imagery collection for natural disasters.
- Expanding National Guard access to EnhancedView imagery to include Title 32 authorities outside of presidentially declared natural disasters.
- Expanding National Guard access to SAR capabilities.

Contents

Figures and Tables

1. Introduction

The National Guard Incident Awareness and Assessment (IAA) mission integrates the planning and employment of traditional intelligence, surveillance, and reconnaissance (ISR) capabilities—including electro-optical (EO) and infrared (IR) sensors, synthetic aperture radar (SAR), multispectral and hyperspectral (MSI/HSI) imaging, and full motion video (FMV)—to provide timely, critical information to local, state, and federal authorities leading responses to state and national emergencies. National Guard IAA capabilities include the tasking, processing, assessment, and dissemination tools necessary for such integration to assist in saving lives, reducing suffering, minimizing property damage, and protecting critical infrastructure and key resources.

Use of commercial satellite imagery (CSI) has become an increasingly integral part of the National Guard and other authorities' responses to major events, particularly natural disasters, affecting the continental United States (CONUS), Alaska, Hawaii, and U.S. territories. The collective response to the four hurricanes that made landfall in CONUS and Puerto Rico in 2017—hurricanes Harvey, Irma, Nate, and Maria—for example, incorporated analysis, distribution, and use of broad-area, high-resolution CSI to an expanded degree, and highlighted to the National Guard the utility of these capabilities in performing IAA. Recent innovations in satellite and sensor technologies, imagery analysis tools, and dissemination methods have also prompted the National Guard to assess the range of CSI capabilities, trends in the development of new technologies and architectures to improve user accessibility, and the extent to which integration of currently available or emerging CSI capabilities would enable the National Guard to more effectively and efficiently meet its IAA mission requirements.

To assist in answering these questions, the National Guard Bureau (NGB) asked the Institute for Defense Analyses (IDA) to provide an overview of current and emerging commercial high-resolution unclassified satellite imagery capabilities and to conduct an analysis of how these capabilities could meet National Guard IAA mission requirements. The National Guard also asked the IDA team to examine the efficacy of current and potential U.S. Government satellite imagery capabilities for supporting IAA mission requirements, such as capabilities that might be provided by the U.S. Geological Survey's (USGS) Earth Resources Observation and Science (EROS) Data Center and Landsat series, the National Oceanic and Atmospheric Administration (NOAA), the National Geospatial-Intelligence (GEOINT) Agency (NGA), the National Reconnaissance Office (NRO), and the General Services Administration (GSA) contract for the Commercial Initiative to Buy Operationally Responsive GEOINT (CIBORG). The National Guard directed the IDA team to focus on the requirements for, and application of, capabilities for the IAA mission specifically in response to natural disasters.

The IDA team reviewed available literature on National Guard responses to recent disasters and conducted interviews with members of the NGB Directorate of Operations (A2/3/6/10) staff; Eagle Vision program office within the Headquarters, Air Force (HAF) ISR Directorate (A2); 169th Communications Flight Eagle Vision IV (South Carolina Eagle Vision unit); and several National Guard Unclassified Processing, Assessment, and Dissemination (UPAD) sites[1] to identify the National Guard's information and satellite imagery requirements for the IAA mission and to capture lessons learned from recent IAA operations, including the response to Hurricane Florence in September 2018. The IDA team researched current and emerging commercial and government capabilities by reviewing available literature, leveraging the IDA team's subject matter expertise, and conducting interviews with the USGS, National Park Service, NGA, and four leading Earth observation satellite imagery companies: Airbus, BlackSky Global, Digital Globe, and Planet, Inc.

[1] IDA interviewed the Ohio 178th Intelligence, Surveillance and Reconnaissance Group (ISRG); California 195th ISRG; Massachusetts 102nd Intelligence Wing; and Arkansas 188th ISRG individually and listened into UPAD coordination calls with multiple state UPAD units during the National Guard's September 2018 response to Hurricane Florence.

2. National Guard Information Awareness and Assessment Requirements

To begin the assessment, the IDA team reviewed IAA and natural disaster relief literature; developed notional "use cases" for responses to fires, floods, hurricanes, volcanic eruptions, and earthquakes; and conducted interviews with National Guard personnel to develop the following representative list of incident commander information requirements, categorized by four IAA mission types based on selected capability package categorizations from the Chairman of the Joint Chiefs of Staff Defense Support of Civil Authorities (DSCA) Execute Order (EXORD).[2] To underpin our assessment framework, the IDA team selected from the DSCA EXORD the four mission types that the National Guard would most frequently support in the event of a natural disaster:

1. Situational Awareness
2. Damage Assessment
3. Search and Rescue
4. Evacuation

The list below provides an example of the broad array of information requirements associated with the National Guard's IAA mission during natural disaster relief efforts. These sample information requirements informed the IDA team's assessment of (1) the utility of various CSI capabilities for satisfying these requirements, and (2) which capabilities the National Guard would need in order to be able to effectively execute the IAA mission and support the DSCA EXORD mission types.

Situational Awareness

- What are the geographic boundaries of the disaster area? Identify and map the hazard zone.
- What areas has the natural disaster already impacted (for example, by flooding, scorching, ground fissures, lava flows) and what areas will it most likely impact next? In what direction is the disaster heading, and where will the next damages occur?

[2] Joint Staff J3, Defense Support of Civil Authorities Execute Order, June 7, 2013.

- What are the most viable lines of communication (LOC) for transporting personnel and supplies and evacuating individuals from the hazard area? What is the operational status of roads, bridges, airfields, ports, and potential helicopter landing zones? Where can responders establish transshipment facilities?
- Are critical utilities such as electricity and water available or working in the area of concern?
- Where are natural barriers (for fires, flooding, lava flows, etc.) and where are the optimal locations to establish additional barriers?

Damage Assessment

- What is the overall extent of infrastructure damage, for instance, impassable LOCs, submerged homes, and collapsed or burned buildings? Where is the damage?
- What is the overall status, usability, and accessibility of critical infrastructure, such as electric power plants and transmission networks, water treatment plants, fuel storage facilities, hospitals, and shelters?
- Are there indications of contamination in the hazard zone due to damage to fuel, sewage, chemical, or other facilities?

Search and Rescue

- Are there populations or individuals who require evacuation or are trapped? Where are they located?
- What areas are most in need of relief supplies and services?
- Which LOCs are most viable for use by search and rescue team vehicles or aircraft?
- Where are suitable landing zones for helicopter rescue?

Evacuation

- What areas should responders prioritize for evacuation?
- What are the most viable exit routes for evacuating individuals from the hazard area?
- Which LOCs require clearance or repair, and where, in order to be viable for evacuation purposes?
- Which LOCs are the ongoing disaster events threatening?
- Where should assembly points be located for persons awaiting transport for evacuation?

- Where are safe refuge zones to which responders will evacuate the population in case of continued flooding, fire, eruptions, and aftershocks?
- What facilities can responders use for population shelters and accommodation in the refuge zones, and where are they located?

3. IAA CSI Requirements

The IDA team's literature reviews, interviews with National Guard UPAD imagery analysts, and the sample National Guard IAA information requirements listed in the previous section informed an analysis of (1) the utility of various satellite imagery capabilities for satisfying these requirements, and (2) which capabilities the National Guard would need in order to be able to effectively execute the IAA mission and support missions such as situational awareness, damage assessment, search and rescue, and evacuation.

During the first 24 to 72 hours of a natural disaster event, the National Guard's top priorities are lifesaving and gaining situational awareness as quickly as possible. During this time, the National Guard seeks to locate damaged areas and assess the relative extent of the damage to identify the requisite resources and to prioritize and deploy them to the appropriate areas. In many cases, this process includes identifying viable ingress routes and staging areas to get responders and supplies into the affected area and egress routes to evacuate threatened populations.

In terms of sensor type, panchromatic (PAN) and multispectral EO are the most widely applicable satellite imagery capabilities for natural disaster response efforts. SAR can be a valuable capability when cloud cover or smoke obscures a disaster area, as with hurricanes, wildfires, or volcanic events. SAR can also be useful when dangerous rain and wind conditions prevent aircraft from flying below the cloud deck. Specialized multispectral analysis products are applicable in specific cases, such as to detect soil contaminants or hazardous materials. However, the most useful application of MSI is the production of full-color products, which provide much better interpretability than PAN imagery.

Having access to fairly current (within a year) high-resolution baseline imagery of an impacted area contributes greatly to the ability to respond quickly and accurately to information requirements. Having recent "before" images of an area days in advance of an impending natural disaster, particularly images taken during the same season and time of year as the anticipated weather event, facilitates more accurate change detection and identification of threats to locations such as vital critical infrastructure and ingress and evacuation routes. Some states use older or lower-resolution imagery from sources such as Google Earth as their baseline imagery and compare it with new images taken after a natural disaster begins.[3] However, other CSI capabilities could contribute to improved, more contemporaneous "pre-disaster" baseline mapping.

Figure 3-1 summarizes our findings on the utility of various sensors for satisfying IAA information requirements for wildfires, hurricanes and floods, earthquakes, and volcanic events.

	Panchromatic	Multispectral (MSI) & Hyperspectral (HSI)			Synthetic Aperture Radar
		Visible & Near Infrared	Shortwave Infrared	Mid- & Long-Wave Infrared	
Common to all Disaster Types	Situational Awareness				
	Search and Rescue/Helo Landing Zone Identification				
	Damage Assessment (DA)/Critical Infrastructure Status				
	Lines of Communication Status (Reception, Staging, Evacuation)				Lines of Communication Status (Weather Obscured)
		Pollution & Soil Contamination (except Wildfire)			
Wildfire	Fire Boundary/Direction		Fire Boundary/Direction (Smoke Obscured, Night)		
	Burned Area Identification				
Hurricane & Flood	Surge/Flood Extent		Power Availability		Surge/Flood Extent (Weather Obscured)
Earthquake			Power Availability		
Volcano	Mapping Ash Cover				
	Mapping Flows				Mapping Lava Flows (Weather Obscured)
	Ash Cloud				

Figure 3-1. Application of CSI Sensors to IAA Requirements

The interviews highlighted a requirement for high-resolution, broad area coverage of disaster areas and frequent revisit rates (one revisit a day minimum) in support of initial situational awareness, especially during the first 24–72 hours of an event. The UPAD analysts indicated that they require a 1.0 m ground sample distance (GSD) resolution or better to meet most IAA information requirements. Specifically, they found that 0.5 m GSD is optimal for satisfying requirements, particularly those for damage assessment. Imagery from airborne assets is preferred, and more effective, for supporting search and rescue missions, as aircraft are able to provide high resolution as a result of low flight altitudes, as well as greater responsiveness and persistence. However, imagery requirements can vary considerably depending on specific circumstances and applications. An analysis of

[3] Interview with 102nd Intelligence Wing, Massachusetts Air National Guard, June 29, 2018.

requirements published in literature for tasks relevant to National Guard natural disaster response is provided below.

A. IAA Imagery Metrics

Many factors contribute to the utility of imagery. The most important are image quality and timeliness. Adequate image quality ensures that image analysts can extract the information that they need, while adequate timeliness ensures that the information is available in time to support decisions.

Imagery analysts often state image quality requirements in terms of the resolution of imagery, which is the most important factor in determining image quality. The GSD is the actual distance between points on the ground represented by adjacent pixels in the image; the ground resolved distance (GRD) is a measure of effective resolution that also includes atmospheric effects and image processing.[4] Imagery users often state timeliness requirements in terms of the mean time to revisit, which is the average time between two images of the same target collected by the platform or system under consideration. Besides frequency, another component of timeliness is the urgency of the first imagery collection.[5] Other factors that sometimes bear on the utility of information include geolocation accuracy and temporal accuracy.[6]

Military acquisition programs for cameras typically specify a requirement for image resolution, often in terms of the National Imagery Interpretability Scale (NIIRS).[7] NIIRS runs from 0 (image not interpretable) to 9 (fine details interpretable) and can be directly linked to GRD. Each level of the NIIRS scale is defined by imagery interpretation tasks that can be performed with imagery of that quality; for instance, a NIIRS 6 image (visual) can be used to detect a closed gate across a single-lane road or to identify the spare tire on a medium-sized truck.

The National Guard presently does not have published requirements for the image quality or timeliness needed for disaster relief operations. We examined the literature to determine what requirements have emerged for tasks similar to those which National Guard imagery analysts conduct during natural disaster response. The figures presented here

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[4] For further detail on image quality, see Institute for Defense Analyses, *Relating Image Quality Metrics*, IDA Paper P-8470, August 2017, and references cited therein.

[5] The Federal Emergency Management Agency (FEMA) breaks down imagery requirements into five parts: urgency, frequency, target area (i.e., size and shape of image needed), resolution, and the analytical requirements for image interpretation. Federal Emergency Management Agency, *Remote Sensing in Federal Disaster Operations*, FEMA 9321.1-PR, June 1999.

[6] G. Bitelli and L. Gusella, “Remote sending satellite imagery and risk management: image based information extraction,” *WIT Transactions on Information and Communications* 39:149-158, 2008.

[7] John M. Irvine, “National Imagery Interpretability Rating Scales (NIIRS): Overview and Methodology,” *Proc. SPIE*, 3128:93, 21 November 1997.

provide a rough estimate of what imagery analysts need. We caution that data from the literature are not complete, are not always consistent, and do not represent validated requirements. We first discuss spatial resolution, then temporal resolution.

1. Spatial Resolution

Table 3-1 provides selected representative spatial resolution requirements found in the literature, and includes separate sections for general situational awareness and damage assessment. Requirements vary by sensor modality. We present resolution requirements for PAN (i.e., visual or EO) imagery, which are most commonly described in the literature.

Table 3-1. Selected PAN Spatial Resolution Requirements in Literature

Relevant to Disaster Type: Hurricanes and Floods	Wildfires	Volcanic Eruptions	Earthquakes	Imagery Interpretation Task	Resolution Required
				Situational Awareness Tasks	
		X		Ash Cloud Monitoring[a]	1 km
		X		Mapping Lava Flows[b]	10 – 30 m
	X			Fire Geolocation[a]	250 m
	X	X		Local Burned Area Assessment[a]	5 m
X				Measuring Flood Peak[a]	30 m
	X			Fire Fuel Mapping[c,d]	5-30 m
X				Flood Damage[a]	2-5 m
				Damage Assessment Tasks	
X	X		X	Rooftop Damage[e,f]	1 – 1.5 m
X	X		X	Damage to Individual Roof Rafters[g]	8 in – 2 ft
X				Windstorm Damage Detection[h]	1 m
			X	Earthquake Damage Assessment[i]	0.6 – 1 m
			X	Earthquake Damage Assessment[b]	1 m

[a] Committee on Earth Observation Satellites (CEOS), *The Use of Earth Observing Satellites for Hazard Support: Assessments and Scenarios*, National Oceanic and Atmospheric Administration, 2003.

[b] C. J. van Westen and Y. Georgiadou, “Spatial data requirements and infrastructure for geological risk assessment,” *Proceedings of the Workshop on Natural Disaster Management, ISPRS Technical Committee VII*, Ahmedabad, India, January 2001.

[c] MSI including near-infrared (NIR) preferred.

[d] Charles W. Dull and Bryan S. Lee, "Satellite Earth Observation Information Requirements of the Wildland Fire Management Community," in Frank J. Ahern et al., eds., *Global and Regional Vegetation Fire*

Monitoring from Space: Planning a Coordinated International Effort, The Hague, The Netherlands: SPB Academic Publishing, 2001.

[e] Sarah E. Battersby, Michael E. Hodgson, and Jiayu Wang, "Spatial Resolution Imagery Requirements for Identifying Structure Damage in a Hurricane Disaster: A Cognitive Approach," *Photogrammetric Engineering and Remote Sensing* 6:625-635, June 2012.

[f] Jiayu Wang, *A Cognitive Assessment of Post-Disaster Imagery Requirements*, M.S. Thesis, University of South Carolina, 2010.

[g] Robert Bolus and Andrew Bruzewicz, *Evaluation of New Sensors for Emergency Management*, US Army Corps of Engineers, August 2002.

[h] Beverley J. Adams and Ronald T. Eguchi, *Remote Sensing for Resilient Multi-Hazard Disaster Response*, Technical Report MCEER-08-0020, Multidisciplinary Center for Earthquake Engineering Research, 2008.

[i] Thomas W. Gillespie et al., "Assessment and Prediction of Natural Hazards from Satellite Imagery," *Progress in Physical Geography* 31(5):459–470, October 2007.

Several points are notable. First, even very low resolution imagery (tens of meters) can have applications to particular tasks. Second, damage assessment tasks generally require better resolution than general situational awareness tasks. Third, certain tasks specify relatively large ranges, implying uncertainty.

In our interviews with UPADs, individual analysts stated that they preferred to work with imagery of better than 1 m resolution for assessing gross building damage from hurricanes and 0.5 m resolution when looking for people as part of a search-and-rescue operation during a wildfire event. The figure for building damage is slightly better than those we have found in the literature, but it is not unreasonable to conclude that analysts may desire slightly better imagery than they would absolutely require. Some studies have noted that even higher resolution imagery provides additional value in disaster response operations. For example, after the May 12, 2008, Wenchuan Earthquake in China, 10–20 cm resolution imagery collected by unmanned aerial vehicles was used to monitor changes in the disaster situation and to make various maps to support relief and recovery plans.[8]

Finally, other sensing modalities may be preferable for specific tasks. For instance, NOAA has published a requirement of 1 km resolution for PAN monitoring of volcanic ash clouds, but NOAA also stated in the same document that 5 km resolution with an IR sensor would also be adequate.[9] PAN cameras are of limited utility at night or where there is heavy cloud cover. IR sensors can operate in low-light conditions and SAR can penetrate vapor clouds. IR imagery detects differences in temperature and can therefore be especially useful for detecting wildfires. For instance, UPAD analysts stated that 30 m short-wave infrared (SWIR) imagery is generally adequate for detecting fires in forests.

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[8] Jing Li et al., "Spatial Information Technologies for Disaster Management in China," in P. Showalter and Y. Lu, eds., *Geotechnologies and the Environment Volume 2*, Heidelberg: Springer-Verlag, 2010.

[9] Committee on Earth Observation Satellites (CEOS), *The Use of Earth Observing Satellites for Hazard Support: Assessments and Scenarios*, National Oceanic and Atmospheric Administration, 2003.

2. Temporal Resolution

There are fewer published requirements for urgency and revisit.

a. Urgency

A 2014 survey of state disaster response leaders asked when information about disaster extent, damage to critical infrastructure, and damage to transportation systems is “too late.” Roughly 70% of respondents said that imagery at 24 hours was useful, 55% that imagery at 48 hours was still useful, and 30% that imagery at 72 hours was useful.[10] Figure 3-2 provides a more detailed breakdown by damage type.

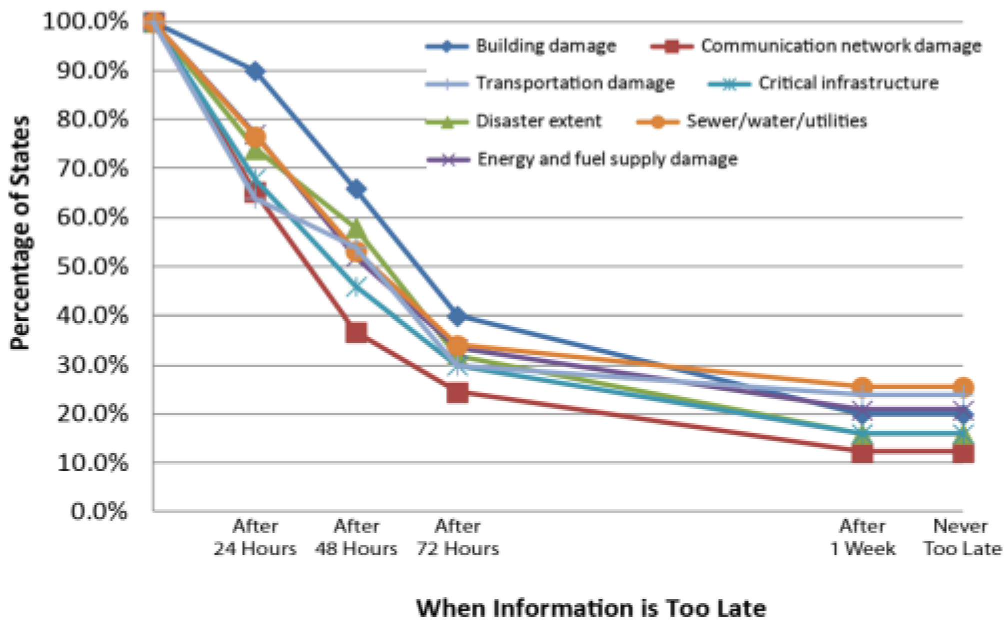

Figure 3-2. Temporal Utility of Information

Source: Extracted from https://irevolutions.org/category/satellite-imagery/

The first 48 hours following a disaster is the critical period for urban search and rescue teams to locate survivors. During this time, imagery collection is essential to obtain a high-

[10] Michael E. Hodgson et al., “Geospatial Data Collection/Use in Disaster Response: A United States Nationwide Survey of State Agencies,” in M. Buchroithner et al., eds., *Cartography from Pole to Pole*, Berlin: Springer-Verlag, 2014.

resolution, synoptic overview of the highway system, in order to monitor structural integrity and rapidly assess the degree of damage.[11]

b. Revisit

Table 3-2 shows selected data from the literature on required revisit rates. Revisit is required for situational awareness tasks but not for damage assessment tasks. Generally, damage assessment can occur once following a disaster.[12] Since earthquakes are generally short in duration, there are no published revisit rate requirements for imagery during earthquakes.

Table 3-2. Selected PAN Revisit Requirements in Literature

Relevant to Disaster Type: Hurricanes and Floods	Wildfires	Volcanic Eruptions	Earthquakes	Imagery Interpretation Task	Revisit Required
Situational Awareness Tasks					
		X		Ash Cloud Monitoring[a]	30 min
	X			Fire Geolocation[a,b]	30 min
	X			Fire Geolocation[c,d]	15 min
	X	X		Local Burned Area Assessment[a]	daily
X				Measuring Flood Peak[a]	hours-days
	X			Fire Fuel Mapping[b]	16 days

[a] Committee on Earth Observation Satellites (CEOS), *The Use of Earth Observing Satellites for Hazard Support: Assessments and Scenarios*, National Oceanic and Atmospheric Administration, 2003.

[b] Charles W. Dull and Bryan S. Lee, "Satellite Earth Observation Information Requirements of the Wildland Fire Management Community," in Frank J. Ahern et al., eds., *Global and Regional Vegetation Fire Monitoring from Space: Planning a Coordinated International Effort*, The Hague, The Netherlands: SPB Academic Publishing, 2001.

[c] Nicolaos I. Sifakis et al., “Wildfire Detection and Tracking over Greece Using MSG-SEVIRI Satellite Data,” *Remote Sensing* 3:524-538, 2011.

[d] Timothy J. Lynham, Charles W. Dull, and Ashbindhu Singh, “Requirements for Space-based Observations in Fire Management,” *IEEE International Geoscience and Remote Sensing Symposium*, Toronto, Canada, 24-28 June 2002.

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[11] Ronald T. Eguchi et al., “Utilizing New Technologies in Managing Hazards and Disasters,” in P. Showalter and Y. Lu, eds., *Geotechnologies and the Environment Volume 2*, Heidelberg: Springer-Verlag, 2010.

[12] However, during our discussions with UPAD cell analysts, they indicated that they are called on to make damage assessments for gross building damage during hurricanes and wildfires at least daily.

The IDA team found two separate revisit estimates (15 minutes and 30 minutes) in the literature for wildfire geolocation. In our interviews with the UPADs, individual analysts stated that fire perimeter awareness requires “persistent” revisit since wildfires can change direction quickly.

4. Status Quo: Satellite Imagery Support to National Guard IAA

In this Chapter, the IDA team discusses the variety of organizations that supply satellite imagery to the National Guard, the characteristics of that imagery—such as sensor type and resolution—and the utility of the imagery for satisfying IAA requirements. We also describe the UPAD analysts' role in analyzing satellite and other types of imagery.

A. National Guard IAA Personnel and Architecture

The National Guard's network of UPADs provide remote all-source, fused analysis, to include imagery analysis and support to incident commanders in affected states. Many of the UPADs have specific specialties. For example, the Indiana, Kansas, and Massachusetts UPADs are multi-intelligence analysis sites, meaning that they can provide satellite imagery (EO, IR, and SAR) analysis as well as analysis of manned and unmanned aircraft (U-2, RQ-4, and MQ-9) imagery; the Kansas, Indiana, Ohio, and Massachusetts UPAD sites have SAR analysis expertise; Arkansas, Nevada, Alabama, and New Mexico can provide FMV analysis, as well as still EO and IR imagery analysis; and the Washington state and Tennessee UPADs provide EO analysis. Nine of the 14 Air National Guard UPAD units are co-located with U.S. Air Force Distributed Common Ground System (DCGS) sites.

In natural disaster response situations, multiple UPADs may provide support and, in some cases, will respond to requirements from more than one state. In previous natural disasters, it has proven effective for UPAD units removed from the disaster area to provide analytic support to affected states. UPAD imagery analysts may provide input to collection managers, but do not task imagery collection directly.

The UPADs disseminate their products through the Domestic Operations Awareness and Assessment Response Tool (DAART), a web-based tool that acts as a repository of GEOINT information from a variety of IAA assets. The National Guard as well as other state and local authorities can access DAART when responding to natural disasters and other large scale domestic events.

B. Current Imagery Resources for National Guard IAA Mission Support

There are three main sources of satellite imagery available to UPAD analysts and other National Guard responders during a natural disaster: satellite imagery from the Eagle

Vision program, other U.S. Government and civil resources, and the International Charter for Space and Major Disasters. We discuss each of these below. In addition, because National Guard imagery analysts have increasingly found “non-traditional” publicly available sources of information—for example, social media—to be useful for meeting information requirements, we also touch on those resources. An analysis of resources used by the National Guard during the September 2018 Hurricane Florence response is provided in Appendix A.

1. Eagle Vision

The Eagle Vision program constitutes the organic Air Force and National Guard capability for directly downlinking and distributing unclassified CSI. HAF A2 manages and funds the program. Eagle Vision’s architecture consists of an acquisition segment that downlinks CSI, an integration segment that processes and formats imagery, and a dissemination segment. The acquisition segment includes five deployable ground stations acquired from Airbus Defence and Space. Active duty Air Force intelligence personnel staff and operate one of these stations at Ramstein Air Base, Germany. The other four ground stations are operated and staffed by the Air National Guard and are located at San Diego Air National Guard Station, California; McEntire Joint National Guard Base, South Carolina; Joint Base Pearl Harbor-Hickam, Hawaii; and Redstone Arsenal, Alabama. Eagle Vision provides CSI support for the majority of domestic disasters by collecting pre-event baseline imagery as well as imagery during and after events.

a. Eagle Vision CSI

Through the Eagle Vision program office's contract with Airbus Defence and Space, the five Eagle Vision ground stations can downlink imagery directly from the SPOT 6, SPOT 7, TerraSAR-X, TanDEM-X, and Pléiades HR-1A and HR-1B commercial satellites. Some of the key features of these satellites are provided in Table 4-1 below.[13]

Table 4-1. Satellites with Direct Downlink to Eagle Vision

	SPOT 6/7	TerraSAR/TanDEM-X	Pléiades-HR 1A/1B
Swath	60 km	4 – 270 km	20 km
Sensors	EO PAN, MSI	SAR	EO PAN, MSI
Resolution (GSD)	PAN: 1.5 m MSI: 6 m	0.25 – 40 m	PAN: 0.5 m MSI: 2 m
Revisit Capacity	Daily	Daily for most latitudes	Daily

[13] Technical specifications taken from Airbus’s website: https://www.intelligence-airbusds.com/en/8289-imagery-services.

Daily Acquisition Capacity	6 000 000 km²	5 400 000 km²	700 000 km²

The Eagle Vision contract does not limit the amount of SPOT 6 and 7 1.5m GSD imagery that Eagle Vision may collect or downlink within the field of view of their ground stations. Airbus has allowed Eagle Vision ground stations to passively downlink all raw SPOT 6 and 7 data as the satellites pass over each station's communications cone.[14] Eagle Vision operators may directly task Pléiades-HR 0.5 m GSD and TerraSAR and TanDEM-X collections; however, they must receive prior authorization from Airbus and Eagle Vision's program management office at Hanscom Air Force Base in Massachusetts, as the program contract provides a more limited amount of funds for imagery from these four satellites. Airbus and HAF A2 have structured the contract such that the Eagle Vision program office can add additional funds throughout the year.

b. Eagle Vision Acquisition: Direct Downlink

Eagle Vision uses a direct downlink (DDL) architecture to acquire imagery from satellites. DDL customers purchase communications and processing ground systems to downlink and produce imagery from satellites from a commercial operator—in Eagle Vision's case, Airbus. A DDL and ground station model is not dependent on an Internet connection to receive the imagery a satellite collects; rather, deployable ground stations can be transported to affected areas during network outages and can receive imagery and disseminate it using hard copies, rather than through the Internet. Eagle Vision units must have telephone or web-based communications to coordinate satellite access windows (SAW) and downlinks with Airbus's missions operations center. Eagle Vision ground stations did not deploy to affected areas for domestic natural disasters examined during the course of this study.

In 2014, the Air Force awarded Airbus a contract for system evolution and maintenance of the Eagle Vision DDL and ground station architecture through 2019.[15] Airbus indicated to the IDA team that the main focus of future upgrades to the current instantiation of Eagle Vision will be to reduce the size of the ground stations and to make them more easily transportable. Today, transporting an Eagle Vision system requires a C-130 aircraft and costs approximately $1 million; however, the Airbus representatives

[14] Passive downlink consists of downlinking all imagery collected by the satellites while they are in the view cone of the Eagle Vision ground station. Tasking collection consists of sending requests for specific downlinks to Airbus to place on the satellite's imaging schedule.

[15] "USAF contracts Airbus for Eagle Vision system for ground satellite stations," Air Force Technology, November 2014. https://www.airforce-technology.com/news/newsusaf-contracts-airbus-for-eagle-vision-system-for-ground-satellite-stations-4453057/

explained that making the system, including the antenna, smaller so that it can fit in a van or transit case could improve deployability and lower operation and maintenance costs.

c. Eagle Vision Dissemination

Eagle Vision distributes the collected imagery by posting the images to their dissemination website, EVR2EST (Eagle Vision & ROVER Responsive Exploitation of Space Products for Tactical Use). UPAD analysts, joint force headquarters, and others can access the imagery posted on EVR2EST, download it, and create products to distribute to incident commanders and other officials.

Additionally, Eagle Vision disseminates the imagery to the USGS Hazard Data Distribution System (HDDS) where it can be even more widely accessed by users from the Federal Emergency Management Agency (FEMA), state emergency operations centers, and other natural disaster response users. The HDDS provides a single, consolidated point-of-entry and distribution system for USGS-hosted remotely sensed imagery and other geospatial datasets related to an event response.[16]

Eagle Vision imagery is also posted to DAART to facilitate National Guard and other state and local authorities' access when responding to natural disasters and other large scale domestic events.

A depiction of the Eagle Vision DDL and imagery dissemination model is shown in Figure 4-1 below.

[16] "Hazards Data Distribution System Fact Sheet," U.S. Geological Survey, June 2015, https://pubs.er.usgs.gov/publication/fs20153048.

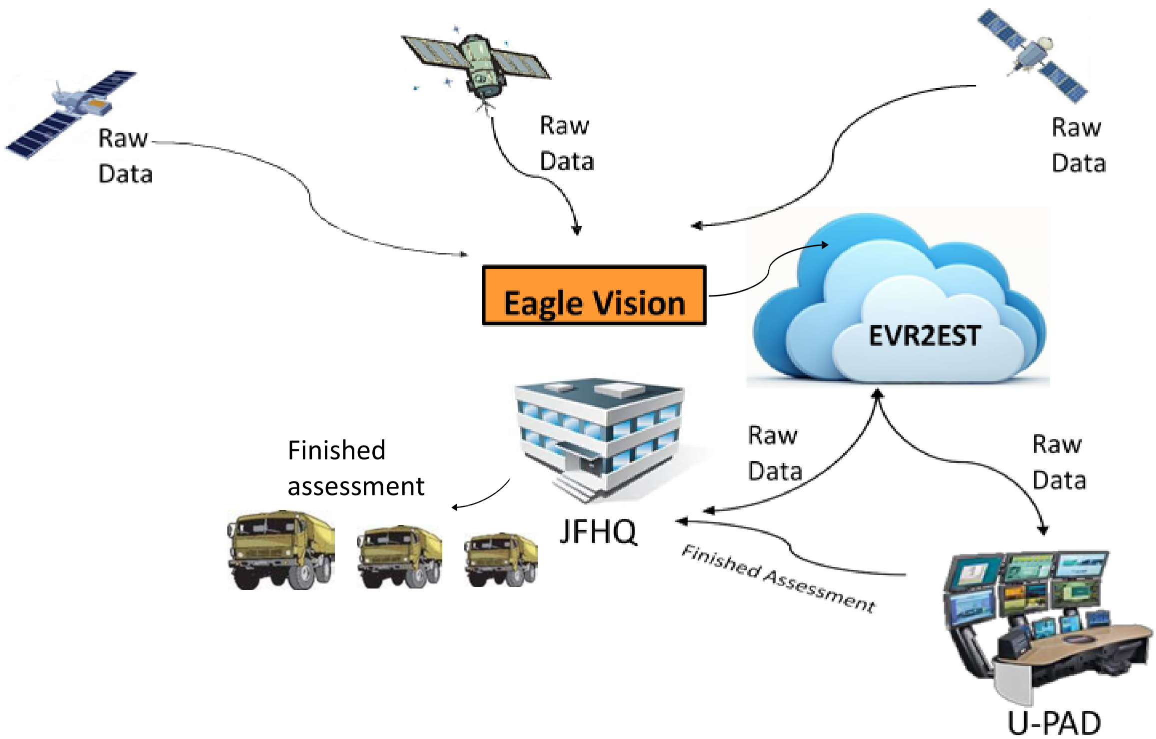

Figure 4-1. Eagle Vision DDL and Dissemination Model

Eagle Vision proactively monitors news of developing or potential natural disasters and begins to collect imagery and disseminate it to EVR2EST when a natural disaster is threatening the U.S., such as an approaching hurricane.

2. Other U.S. Government Resources

The National Guard also has access to satellite imagery from a wide range of other U.S. Government agencies. Most of this imagery is made available through the USGS EROS Center repository, for dissemination via HDDS.

a. USGS

Through the EROS Center and HDDS, USGS provides a repository and dissemination for imagery data from a variety of government, international, and commercial sources. National Guard UPAD analysts typically leverage access to the HDDS repository for imagery provided by multiple sources. However, much of the imagery is broad area Earth mapping data characterized by low resolution and long revisit times, and supports scientific rather than natural disaster relief applications. Imagery derived from the Landsat satellites in particular fits this description. USGS has primary responsibility for operating the Landsat satellites, creates Landsat imagery products, disseminates Landsat imagery from the EROS Data Center archive, and posts the imagery on HDDS when relevant to a disaster.

The Landsat 8 satellite payload consists of the Operational Land Imager and the Thermal IR Sensor, which provide seasonal coverage of the global landmass at a spatial resolution of 30 meters—visible, near-infrared (NIR), SWIR; 100 meters (thermal); and 15 meters (PAN).[17] National Guard UPAD analysts indicated during multiple interviews that these sensors and the low-resolution mapping imagery they provide are typically insufficient for natural disaster relief applications.

b. NASA

The National Aeronautics and Space Administration (NASA) supports the collection and analysis of data from the Landsat system in collaboration with USGS. NASA also provides imagery from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), an instrument that it operates jointly with Japan's Ministry of Economy Trade and Industry. ASTER sits onboard NASA's Terra satellite and supports climate research through monitoring of environmental changes. ASTER provides visible and NIR imagery across 14 spectral bands, with GSDs ranging from 15 m to 90 m.

c. NOAA

NOAA often provides imagery collected by its aerial remote sensing and space-based weather monitoring assets to USGS for posting on HDDS. NOAA operates the Geostationary Operational Environmental Satellite system (GOES), which uses geosynchronous satellites to support U.S. weather monitoring and forecasting, storm tracking, and meteorology research. The newer GOES satellites, part of the GOES-R series, can provide images and real-time mapping of weather patterns including lightning, cloud, and solar activity, as well severe storms and hurricanes, as frequently as every 30 seconds. The system seeks to provide advanced imagery and improve detection and monitoring of weather systems and hazards in the western hemisphere.[18] The GOES-R series provides high spatial and temporal resolution imagery through 16 spectral bands at visible and IR wavelengths.

d. NGA and NRO

NGA and NRO work collaboratively to provide satellite imagery to U.S. agencies. In the context of imagery resources available to the National Guard for IAA in disaster response, the most relevant imagery source is DigitalGlobe CSI, which NRO and NGA contract and acquire through the EnhancedView program. In August 2018, NGA transferred CSI acquisition authority for EnhancedView to the NRO, along with most of

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[17] "Landsat 8 Overview," National Aeronautics and Space Administration, https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-overview/.

[18] "GOES-R Series Mission," The NOAA National Environmental Satellite, Data, and Information Service, https://www.nesdis.noaa.gov/GOES-R-Mission.

the operational responsibility. Functionally, this transfer does not change the CSI capability DigitalGlobe provides to the U.S. Government through the original EnhancedView contract, at least through the original contract period, which ends in August 2020. Details are provided below.

In 2010, NGA awarded two 10-year contracts totaling $7.3 billion to DigitalGlobe and GeoEye—a CSI vendor subsequently acquired by DigitalGlobe in 2013—for satellite tasking rights, delivery of the imagery collected at NGA's direction, and access to all EO imagery in DigitalGlobe's archive, including all imagery collected in support of other customers. Under NGA's EnhancedView contract, DigitalGlobe has provided the U.S. Government, Intelligence Community, Department of Defense (DoD), and civil agencies access to nearly all imagery the company collects from its WorldView-1, WorldView-2, and WorldView-3 satellites, as well as modest amounts of imagery from the GeoEye-1 satellite. DigitalGlobe recently launched WorldView-4 in 2016, but the EnhancedView contract has not provided access to imagery from that satellite. Technical specifications for these satellites are provided in Chapter 4.

In a recently adopted tasking model known informally as "alternate revolutions," NGA gained full direction of tasking on alternate passes of WorldView 1, WorldView 2, and WorldView 3.[19] This arrangement improved NGA's "pre-emptive" tasking rights—the ability to displace tasking for any other customer—increasing predictability for NGA tasking and significantly reducing complexity for tasking deconfliction. Because the bulk of NGA's imagery targets is located outside the United States, this arrangement has also resulted in significant, but currently unused collection capacity over CONUS.[20]

The EnhancedView program also provides all U.S. Government users who hold a DoD Common Access Card (CAC) access to all EnhancedView-licensed DigitalGlobe imagery, through DigitalGlobe's Global Enhanced GEOINT Delivery (G-EGD) web-based portal, often also known as EnhancedView Web Hosting Service (WHS). Federal employees who do not hold DoD CACs may obtain manual log-in credentials with NGA approval.

On August 31, 2018, NGA transitioned most of the EnhancedView program contract execution to the NRO. NRO renamed the contract EnhancedView Follow On (EVFO). The EVFO contract provides the following services through the year 2020:

[19] NGA originally had control of 61% of DigitalGlobe tasking rights, but the adjudication process for allocating tasking among multiple DigitalGlobe customers was complex and made it difficult to predict when NGA would have access to a particular location. The "alternate revolutions" replaced the "priority ladder" model.

[20] NGA and NRO may legally collect satellite imagery over the United States as long as no U.S. persons can be identified by the imagery.

- Tasking DigitalGlobe with imagery collection—in support of requirements submitted by NGA—on the behalf of all intelligence, defense, and civil federal agencies, including collection over CONUS when a natural disaster is threatening the United States.
- Access to DigitalGlobe's imagery archive, through the National System for Geospatial-Intelligence imagery discovery and access points.
- A secure network architecture in the Secret/Collateral domain for requirement adjudication, tasking, and imagery delivery and when necessary due to reasons of national security.
- Licensing of DigitalGlobe imagery for U.S. Government use.

NGA retains contractual authority for DigitalGlobe's G-EGD web portal contract. Under this contract, DigitalGlobe continues to provide the U.S. Government access to orthorectified imagery across all security domains, including the unclassified, open Internet. G-EGD provides the only access to analysis-ready imagery in the unclassified domain. It also provides limited web-based imagery analysis capabilities.

It is important to note that NGA's G-EGD contract provides the above capabilities only for DigitalGlobe CSI licensed through NRO's EVFO contract. If NRO terminates or modifies DigitalGlobe's EVFO contract, it will impact the capabilities that DigitalGlobe provides under NGA's G-EGD contract. The two contracts are inextricably linked at present.

As described earlier, DigitalGlobe's EVFO contract is currently scheduled to expire in August 2020. NRO, with NGA collaboration, is developing a commercial imagery acquisition strategy for the ensuing years. It is possible that contracts with multiple commercial imagery providers will replace EVFO. NRO has options to further extend DigitalGlobe's EVFO contract beyond 2020 if other vendors' CSI is not yet capable of meeting U.S. Government imagery requirements. In short, NRO and NGA intend to continue supporting acquisition of CSI for the foreseeable future.

In summary, the NRO EVFO contract provides tasked imagery collection, processing, and dissemination over U.S. Government networks, and the NGA G-EGD contract provides WHS portal access, analysis-ready imagery, and limited value-added analytic capabilities across U.S. Government domains, but primarily on the unclassified open Internet.

Currently, for disaster response purposes, the National Guard is only authorized to access DigitalGlobe imagery via NGA G-EGD following a presidential major disaster or emergency declaration. Although National Guard personnel are capable of accessing DigitalGlobe imagery at any time using CAC credentials, per previous NGA General Counsel guidance, they are technically not authorized to do so for disaster responses that occur solely within the purview of state, local, tribal, and territorial authorities. NGA considers this guidance to be consistent with the intent of National Intelligence Program and Military Intelligence Program resources used to fund the EVFO contract. This view also reflects an intent to ensure that the National Guard uses EVFO imagery for natural disaster relief and response purposes and does not disseminate the imagery so widely that it might undermine DigitalGlobe's commercial revenue opportunities, such as business with insurance companies or local governments during and subsequent to recovery and reconstruction efforts.

NRO and NGA are considering concepts of operations (CONOPS) in support of natural disaster response that could dramatically increase CONUS CSI collection in the event of a disaster. NRO and NGA are also considering the addition of commercial SAR capabilities to their portfolio of EVFO imagery at some point in the future, although it is not clear precisely when that will occur. NGA expects any additional SAR capability to be provided through a contractual arrangement subsequent to the current EVFO contract, and thus it will not likely be available until 2021.

NGA has indicated that there may be some latitude to provide the National Guard access to imagery, through G-EGD, prior to events that can be reasonably expected to result in a presidential major disaster or emergency declaration. Coupled with a CONOPS for increasing DigitalGlobe CONUS collection prior to and during disasters, such an arrangement has the potential to improve the availability and utility of DigitalGlobe high-resolution (0.5 m GSD) imagery for National Guard IAA.

NGA suggests that the National Guard collaborate with FEMA and Department of Homeland Security (DHS) to advocate for implementation of the above CONOPS to improve the U.S. Government's response to CONUS disasters. FEMA and DHS both have GEOINT Departmental Requirement Officers at NGA that coordinate adjudication of associated imagery requirements. It is not clear to what extent the National Guard will have visibility into, or be able to provide direct input to, NGA Statements of Capabilities for future CSI, such as the replacement for the existing EVFO, but certainly DHS and FEMA will have such an opportunity.

e. FEMA

Although FEMA does not operate or provide any organic satellite imagery assets or services, when the President issues a major disaster or emergency declaration for a natural disaster in the U.S., FEMA provides CSI requirements to NGA. NGA subsequently adjudicates and satisfies these requirements through National Technical Means or through the EVFO and G-EGD contracts. The FEMA and DHS GEOINT Departmental Requirements Officers located at NGA facilitate the adjudication of associated requirements. FEMA may also utilize federal natural disaster relief funding mechanisms for other assets, such as airborne platforms. For example, FEMA often tasks the Civil Air

Patrol (CAP) for imagery collection. CAP has over 500 aircraft at its disposal and can collect EO, HSI, and FMV imagery.

f. GSA CIBORG

The GSA and NGA designed CIBORG to leverage both NGA expertise and functional management responsibilities and GSA centralized procurement services to make existing and emerging GEOINT products and services available for rapid acquisition. The vision of CIBORG is to provide efficient and responsive access to emerging commercial imagery, data, analytics, and services through an NGA-established GEOINT marketplace; expand access to GEOINT across all levels of government; and enable greater insight and sharing of GEOINT. The GSA leverages multi-agency procurement authorities to get suppliers onto the schedule quickly and simplify discovery of Earth observation products and services.

However, less than 10% of the current products and services offered through the CIBORG initiative consist of imagery-derived products or related analytics. An examination of NGA's 52 exemplars of "Earth Observation Solutions Vendors" as part of the GSA IT Schedule 70 reveals that the greatest portion of CIBORG products, 44%, consist of Systems Engineering and Technical Assistance (SETA) staffing services rather than imagery-derived products. Figure 4-2 below provides a detailed depiction.

CSI contracts (with the sole exception of Planet's contract) currently available via the CIBORG program are structured for the purchase of GEOINT on a per-image basis, a model that does not fit well with National Guard natural disaster relief operations that often require imagery of broad areas, such as the coastline of several states during Hurricane Florence, rather than a few discrete point targets.

IDA's research found that this program does not align well with the National Guard's imagery requirements for the IAA mission.

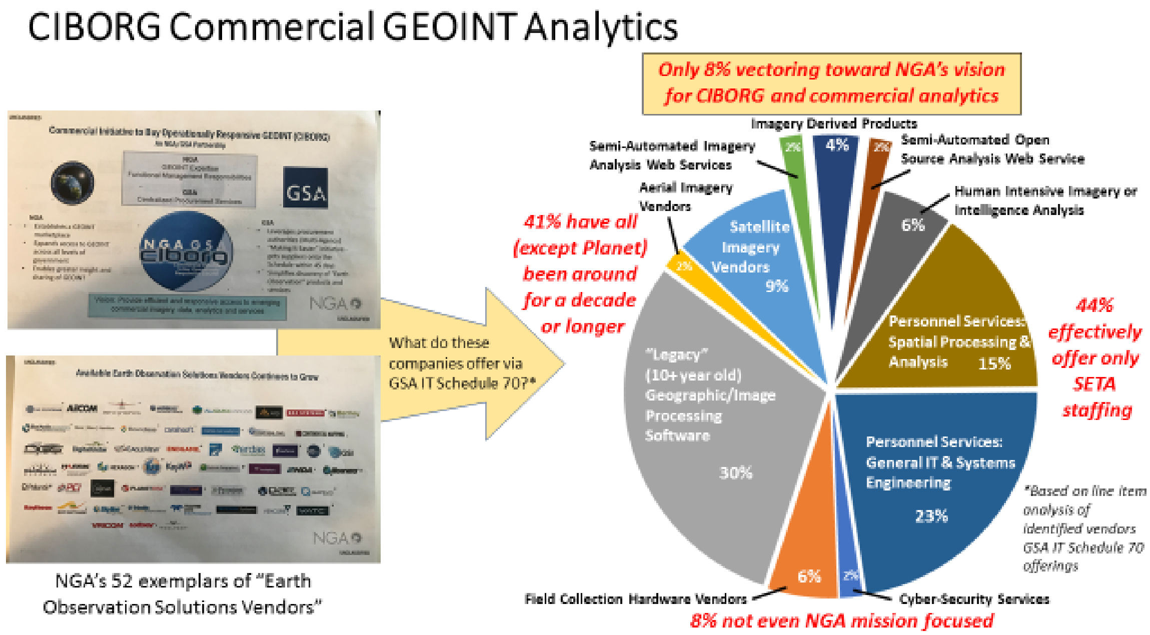


Figure 4-2. GSA CIBORG

3. International Charter for Space and Major Disasters

The International Charter for Space and Major Disasters ("the Charter") is a worldwide collaboration of space-related organizations who contribute their assets, expertise, and resources in response to natural disasters. The Charter has the following two objectives:[21]

- "Supply during periods of crisis, to States or communities whose population, activities or property are exposed to an imminent risk, or are already victims, of natural or technological disasters, data providing a basis for critical information for the anticipation and management of potential crises;"
- "Participation, by means of this data and of the information and services resulting from the exploitation of space facilities, in the organisation of emergency assistance or reconstruction and subsequent operations."

There are 17 Charter Members and 19 Charter Partners that provide access to imagery from a total of 34 satellites. Participation in the Charter is voluntary, and the organizations that contribute imagery do not receive monetary compensation. The USGS HDDS serves as a repository for Charter-collected imagery that parties participating in disaster relief

[21] "Text of the Charter," International Charter Space and Major Disasters, https://disasterscharter.org/web/guest/text-of-the-charter.

efforts may access and use free of charge. During disasters, USGS collects and publishes information needs to the organizations that provide imagery, and those organizations satisfy those needs to the extent feasible, but only at a level that they are willing to support. It is important to note that organizations are not required to contribute all of the imagery they collect that is relevant to the particular disaster.

Though the Charter was primarily designed to benefit countries that have few or no satellite or airborne assets of their own to rely on during natural disasters, any country or state may request through an Authorized User that the Charter be activated. In the case of the U.S., USGS activates the Charter on behalf of FEMA or individual states.[22] USGS activates the Charter a few times per year on average. Although the Charter provides valuable imagery, the National Guard cannot rely upon its activation (and thus the imagery it supplies) for all natural disasters. It is unlikely that USGS will activate the Charter for smaller-scale natural disasters and associated relief efforts managed exclusively by state and local authorities.

Once USGS activates the Charter, National Guard UPAD analysts can pull Charter imagery from HDDS to meet IAA information requirements.

4. Other Resources

Emergency response operations rely on the fusion of all available information, not just satellite or airborne imagery. When creating products in response to information requirements, UPAD analysts synthesize information from a myriad of sources, including traffic cameras, social media (e.g., Twitter, DATAMINR), real-time flood mapping, reports from first responders, and Google Earth, when available. The National Guard is increasingly relying on such sources to tip and cue imagery collection and analysis, and leverages this kind of information particularly in the first days of hurricanes and other major storms when cloud cover and strong winds inhibit the use of aircraft and clear collection from satellites. Appendix A provides additional details on nontraditional sources used during the National Guard's response to Hurricane Florence in September 2018.

[22] Recent U.S. activations of the Charter are listed in Appendix B.

5. CSI Capabilities

The National Guard also tasked the IDA team with investigating the range of CSI capabilities available today and where the industry is heading in the near future. To inform our analysis, we conducted interviews with senior representatives from four companies in the commercial satellite industry: Airbus Defence and Space, the current CSI vendor for the Eagle Vision program; DigitalGlobe, the current EVFO/G-EGD provider; Planet, who has a relatively modest CSI contract with NGA; and BlackSky Global, who will launch their first two operational satellites in November–December 2018, and are constructing 18 additional satellites for launch by 2020. The IDA team selected these companies for in-person interviews based on their leading positions in the CSI market. We provide a detailed description of the capabilities provided by the four vendors in the sections below, as well as a matrix of these capabilities and the natural disaster response applications they can support in Appendix C.

Based on our research, we found the following CSI capabilities were characteristic of the majority of CSI vendors investigated during the course of our study:

- Medium-to-high-resolution sensors
- Web-based satellite tasking, imagery delivery, and imagery access
- Online analytic services through user-friendly interfaces
- Ubiquitous imagery collection, with a focus on analytics
- An emphasis on broad area collection to cue point-target collection

This list provides a general description of how the CSI industry is positioning itself for future capabilities.

A. Airbus Defence and Space

The Air Force currently has an annual contract with Airbus Defence and Space that provides Eagle Vision access to the SPOT 6/7, TerraSAR-X and TanDEM-X, and Pléiades HR-1A/1B portion of Airbus's larger satellite constellation. As described in Chapter 3, this contract offers Eagle Vision unlimited access to SPOT imagery collected within downlink range of Eagle Vision ground station locations, and limited access to Pléiades-HR and TerraSAR-X imagery. Airbus's end user license agreement allows any Intelligence Community, DoD, and civil U.S. Government entity to use imagery that Eagle Vision collects. Additionally, these U.S. Government entities may provide such imagery to state, local, tribal, and territorial governments; foreign governments; and intergovernmental, nongovernmental, and other non-profit organizations.

In their interview with the IDA team, Eagle Vision Program Office representatives cited this liberal license as a key attribute of their imagery contract with Airbus, as it allows National Guard Eagle Vision units to collect and disseminate imagery to state agencies while in Title 32 status.

Airbus Defence and Space is also a participant in the International Charter for Space and Major Disasters. As such, it volunteers imagery from its constellations through HDDS at no cost for parties directly involved in natural disaster relief efforts, when USGS or another authorized user activates the Charter.

1. Current Capabilities

Airbus Defence and Space collects Earth observation satellite imagery from a constellation consisting of SPOT 6 and 7, Pléiades-HR 1A and 1B, TerraSAR-X, TanDEM-X, and PAZ, the Disaster Monitoring Constellation (DMC), KazEOSat-1, and TripleSat.[23] Some of the technical specifications of this constellation are shown in Table 5-1 below. As noted, Eagle Vision's contract with Airbus provides access to the satellites and corresponding capabilities highlighted in blue, but Airbus could provide access to additional satellites under a different contractual arrangement if desired.

Table 5-1. Airbus Satellite Capabilities (Source: Airbus)

	Swath	Sensors	Resolution (GSD)	Revisit Capacity	Daily acquisition capacity
Pléiades Neo	14 km	EO PAN, MSI	Pan: 30 cm MSI: 1.2 m	Twice daily, anywhere	2,000,000 km^2
Pléiades-HR 1A/1B	20 km	EO PAN, MSI	Pan: 0.5 m MSI: 2 m	Daily, everywhere	700,000 km^2
SPOT 6/7	60 km	EO PAN, MSI	Pan: 1.5 m MSI: 6 m	Daily, everywhere	6,000,000 km^2
TerraSAR-X, TanDEM-X, and PAZ	4-270 km	SAR	0.25 m-40 m	Daily for most latitudes	5,400,000 km^2
DMC	640 km	EO PAN, MSI	MSI: 22 m	Daily to every 2 days, everywhere on Earth	22,000,000 km^2
KazEOSat-1	20 km	EO PAN, MSI	Pan: 1 m MSI: 4 m	2-3 days	220,000 km^2
TripleSat	24 km	EO PAN, MSI	Pan: 0.8 m MSI: 3.2 m	Daily, everywhere	600,000 km^2

[23] Technical specifications taken from Airbus's website: https://www.intelligence-airbusds.com/en/8289-imagery-services.

Airbus's Direct Receiving Stations, on which Eagle Vision ground stations are based, may receive DDL of imagery from the SPOT, Pléiades-HR 1A/1B, TerraSAR-X, and TanDEM-X satellites. This constellation offers EO and SAR capabilities of varying resolutions, broad area coverage, and daily EO revisit, while the DDL capability is intended to reduce latency—the time between a request and the imagery reaching the user—and guarantee receipt of data to users in disadvantaged environments, or areas that do not allow for an Internet connection. During their IDA interview, Airbus asserted that, without DDL, the time between tasking a sensor and receiving imagery from the satellite can be on the order of 24 hours or longer. With DDL, however, it may take only a few hours from the time of the initial request or tasking for a ground station to receive a downlink.

Airbus also offers a satellite tasking service called One Tasking, which allows customers to task specified sensors to collect imagery within desired areas, dates, timeframes, and frequencies.

2. Future Capabilities

Airbus is in the process of integrating Pléiades Neo into its constellation, which the company expects will become operational in 2020. Pléiades Neo will consist of a series of small high-resolution (30 cm GSD), six-band MSI EO satellites and, like Pléiades-HR 1A/1B, will support direct tasking.

Airbus representatives told the IDA team that the company has also been focused on broad area coverage, improving imagery analysis and assessment tools, and progressing to the point that sensors could automatically "tip and cue" others to image specified areas; for example, when anomalous characteristics or changes are detected by one satellite and a different type of sensor and resolution over the area could provide additional insight.

3. Possible Contract Options

Should the National Guard desire access to Airbus's other satellites, such as the forthcoming Pléiades Neo, or current and future Airbus tasking and analytic capabilities, it would have to establish and fund a separate CSI contract with Airbus.

B. DigitalGlobe

DigitalGlobe was founded in 1992 as WorldView Imaging Corporation. The company launched QuickBird in 2001, which was the world's highest resolution commercial satellite at that time. Subsequently, the company launched the WorldView series, beginning with WorldView-1 in 2007. Each of the new satellites provided upgrades in spectral content, resolution, and/or capacity. In 2013, DigitalGlobe acquired GeoEye, another U.S. commercial imaging satellite operator, following NGA's cancellation of GeoEye's

EnhancedView contract in 2013 due to sequestration related budget cuts. In 2016, DigitalGlobe purchased The Radiant Group, a geospatial technology services company specializing in big data analytics. MacDonald, Dettwiler and Associates (MDA) acquired DigitalGlobe in 2017 and rebranded the combined company as Maxar Technologies. Maxar's lines of business are summarized in Figure 5-1. DigitalGlobe is also a participant in the International Charter for Space and Major Disasters. The company provides access to WorldView imagery through HDDS at no cost for individuals and organizations directly involved in natural disaster relief efforts. However, DigitalGlobe posts on HDDS only a portion of the total disaster-relevant imagery it collects.

Figure 5-1. Maxar Technologies Business Units

1. Current Capabilities

DigitalGlobe currently operates GeoEye-1, WorldView-1, WorldView-2, WorldView-3, and WorldView-4. We summarize the capabilities of these satellites in Table 5-2. NRO, through the EVFO contract, has full control of tasking on alternate passes of each satellite, with the exceptions of GeoEye-1 and WorldView-4. Subsequent to the WorldView-4 launch, DigitalGlobe offered NGA the opportunity to add WorldView-4 imagery collection to their EnhancedView contract (at an additional cost). NGA declined this offer, and DigitalGlobe subsequently sold foreign customers WorldView-4 capacity. DigitalGlobe has committed to its foreign customers that it will not contract with the U.S. Government for pre-emptive tasking on WordView-4. In other words, DigitalGlobe's foreign customers retain exclusive access to WorldView-4.

Table 5-2. DigitalGlobe Satellite Capabilities

	Sensors	Bands	Resolution (GSD)	Swath (at nadir)	Revisit*
GeoEye-1	PAN + Multispectral PAN Only EO/NIR Multispectral Only	PAN: 450-800 nm Blue: 450-510 nm Green: 510-580 nm Red: 655-690 nm NIR: 780-920 nm	PAN: 0.46 m EO/NIR MSI: 1.84 m	15.2 km	2.1 – 8.3 days
WorldView-1	PAN	PAN: 450-800 nm	PAN: 0.5 m	17.6 km	1.7 – 5.9 days
WorldView-2	PAN EO/NIR Multispectral	PAN: 450-800 nm Coastal: 400-450 nm Blue: 450-510 nm Green: 510-580 nm Yellow: 585-625 nm Red: 630-690 nm Red Edge: 705-745 nm NIR1: 770-895 nm NIR2: 860-1040 nm	PAN: 0.46 m EO/NIR MSI: 1.84 m	16.4 km	1.1 – 3.7 days
WorldView-3	PAN EO/NIR Multispectral SWIR Multispectral 12 CAVIS** Bands	PAN: 450-800 nm EO/NIR: 400-1040 nm SWIR: 1195-2365 nm CAVIS: 405-2245 nm	PAN: 0.31 m EO/NIR MSI: 1.24 m SWIR MSI: 3.70 m CAVIS: 30.00 m	13.1 km	<1.0 – 4.5 days
WorldView-4	PAN EO/NIR Multispectral	PAN: 450-800 nm Blue: 450-510 nm Green: 510-580 nm Red: 655-690 nm NIR: 780-920 nm	PAN: 0.31 m EO/NIR MSI: 1.24 m	13.1 km	<1.0 day
Notes	* Revisit times depend on GSD and look angle **CAVIS = Clouds, Aerosol, Vapor, Ice, Snow				

DigitalGlobe delivers imagery in National Imagery Transmission Format (NITF) 2.1, with processing for radiometric corrections and geometric corrections that geolocate (but do not orthorectify) the imagery to 20 feet circular error at 90 percent probability (CE90) or linear error at 90 percent probability (LE90) geopositioning accuracy.

G-EGD, often called EnhancedView WHS, provides U.S. Government users access to pan-sharpened MSI, orthorectified, and ready for geospatial information systems (GIS) ingest and analysis in either Geo-Tagged Image File Format (GeoTIFF) or NITF 2.1. Additionally, G-EGD provides for Web-based discovery and download for all EnhancedView imagery DigitalGlobe collects, usually within 12 to 24 hours of collection by the satellites. G-EGD is accessible on multiple security domains and platforms through a web browser and also provides an Applications Programmer Interface (API) for integration into any customer's own software application.

DigitalGlobe has also implemented an advanced imagery analysis architecture that includes machine learning approaches, called the Geospatial Big Data Platform (GBDX).

GBDX allows users to implement their own algorithms on imagery “at rest” in DigitalGlobe’s cloud environment, eliminating users’ need to invest in high-performance image processing hardware or software, or the inconvenience and time to download DigitalGlobe imagery. GBDX also provides “pre-built” algorithms. For example, GBDX could assist in determining the level of flooding in a city following a hurricane or the length of a fire line during a wildfire. U.S. Government users can order a GBDX subscription through a GSA pricing schedule; however, as with G-EGD, DigitalGlobe’s GSA pricing only provides access to EVFO-licensed imagery.

In short, DigitalGlobe has structured both their NGA G-EGD and GSA GBDX offerings in such a way that pricing is valid only so long as the NRO independently maintains an EVFO Service Level Agreement with DigitalGlobe.

On September 10, 2010, DigitalGlobe announced that SAR imagery from Maxar's MDA RADARSAT-2 satellite would become available to service subscribers on October 1, 2018.

2. Future Capabilities

DigitalGlobe plans to expand both analysis capabilities and satellite imagery collection capacity. The company is currently developing WorldView replacement satellites, which will form a constellation called WorldView Legion. The WorldView Legion constellation will consist of smaller, more numerous satellites than DigitalGlobe’s current WorldView constellation. The company plans to launch the initial WorldView Legion satellites into polar, sun-synchronous orbits, and subsequent satellites into highly inclined orbits to provide better access to mid-latitude locations. The company expects the WorldView Legion fleet to double DigitalGlobe capacity for its highest-resolution imagery and triple capacity over the parts of the planet with the highest imaging demands.

DigitalGlobe stated that it is also developing, in partnership with a Saudi Arabian company, a network of six Scout satellites that would provide lower-resolution imagery but faster revisit rates. DigitalGlobe expects to launch the Scout constellation in 2019 and anticipates that the combination of its existing capabilities with the Scout and Legion fleets will yield revisit rates of 20 to 30 minutes over some of the most sensitive locations on the globe.

3. Possible Contract Options

Option 1: Expanding National Guard Access to G-EGD for Natural Disasters

DigitalGlobe suggested that the company would be amenable to working with NRO and NGA to modify the existing EVFO and G-EGD contracts to allow for National Guard use of EVFO imagery at any time for the purposes of domestic disaster support (i.e., natural disasters that do not prompt a presidential major disaster or emergency declaration) as long as the imagery is disseminated to state, local, and non-governmental organizations solely for non-commercial natural disaster relief purposes. For example, DigitalGlobe offered that it would be feasible to add a humanitarian events clause to provide support to U.S. natural disaster response, especially if such a clause included language to protect DigitalGlobe from improper sharing of imagery that could undermine commercial business.

Note that this option does not require the use of the WorldView hardware and software that the Air Force has installed in the Eagle Vision systems.

NGA EVFO tasking to NRO can take advantage of the full capacity of EVFO WorldView satellites on each satellite's alternate revolution (orbit). As noted earlier, this has resulted in significant excess capacity over CONUS. The National Guard could establish standing collection requirements over the entire anticipated area of interest for an impending disaster and request NRO to execute the maximum possible imagery collection over that area for a certain number of days prior to an anticipated event such as hurricane landfall and for a certain number of days after the event. A standing collection plan and blanket coverage of the entire area would eliminate the need for NRO to prioritize and adjudicate numerous point targets individually, resulting in more collection—all through an automated process that requires no direct tasking.

This approach eliminates the need to utilize Eagle Vision DDL and minimizes training requirements, as National Guard users would only need to know how to operate G-EGD, which UPAD operators already use. DigitalGlobe indicated that it could provide training to National Guard units on a regular basis, if necessary. Option 1 is depicted in Figure 5-2.

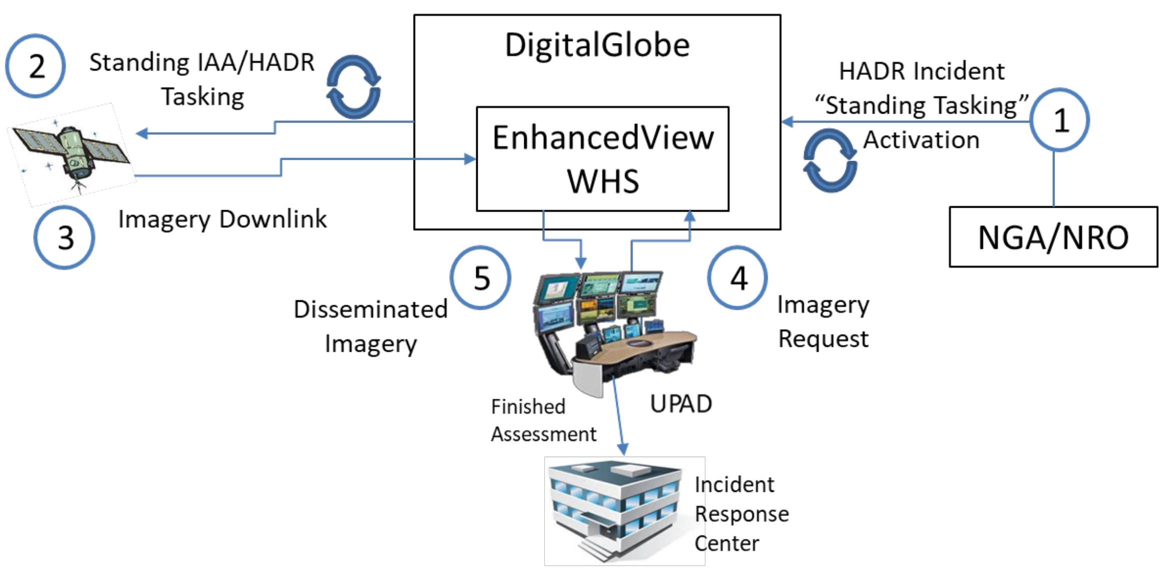


Figure 5-2. DigitalGlobe Architecture Option One: Expanded Use of G-EGD Services

In anticipation of a potential desire by the National Guard to use a DDL capability, DigitalGlobe also introduced two options by which the National Guard could establish WorldView DDL under a separate contract. All Eagle Vision systems have hardware and software in place to support downlink and processing of imagery from the existing WorldView constellation; however, this WorldView DDL capability for Eagle Vision is not currently operational.

Option 2: WorldView Direct Uplink and Downlink

Option 2 is based on the Navy's Coalition Tactical Awareness and Response DDL model. In this option, DigitalGlobe would adjudicate the SAW, and Eagle Vision would directly task the satellite and receive the downlink, using the WorldView DDL capability already installed in the Eagle Vision systems. In addition to providing for direct tasking, this option would not be reliant on NRO's EVFO contract, as it would use DigitalGlobe's commercial capacity on their alternate revolutions. This option would require a direct contract between the NGB and DigitalGlobe. Figure 5-3 summarizes Option 2.

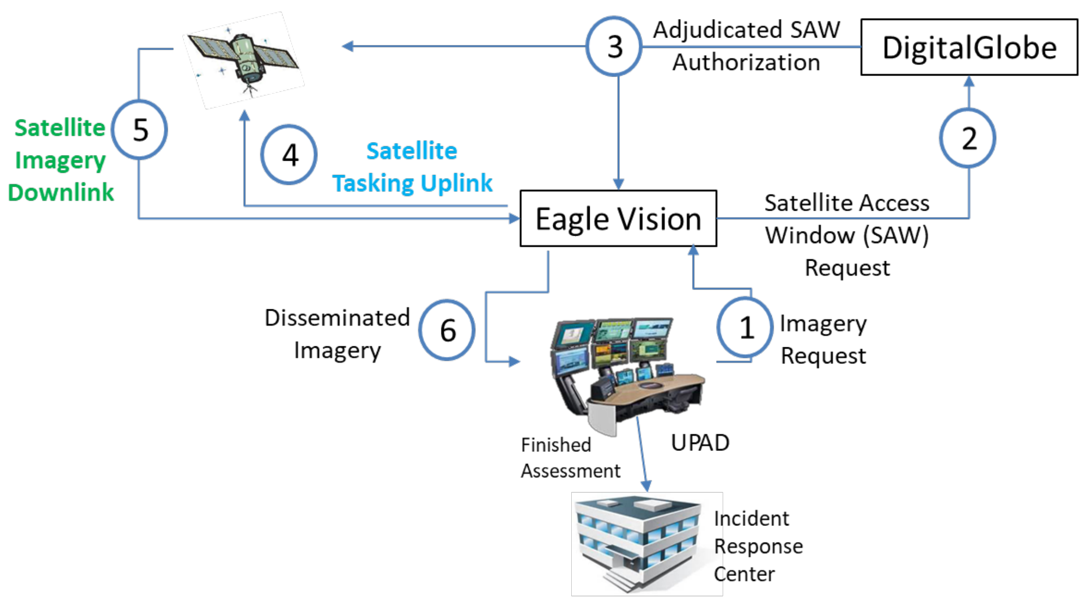


Figure 5-3. DigitalGlobe Architecture Option Two: WorldView Direct Uplink and Downlink

Option 3: WorldView DDL Only

Option 3 would be somewhat in between the first two options. Eagle Vision would be able to receive satellite imagery directly via downlink but would not be capable of direct tasking. This might allow the system to be deployable in the field and could leverage the existing EnhancedView contract with some modification. On the other hand, NRO, NGA, and DigitalGlobe would each need to undertake architecture modifications, which would require significant investments by all parties. DigitalGlobe did not indicate whether this approach would also impose additional costs on their current EVFO contract. Option 3 is displayed in Figure 5-4.

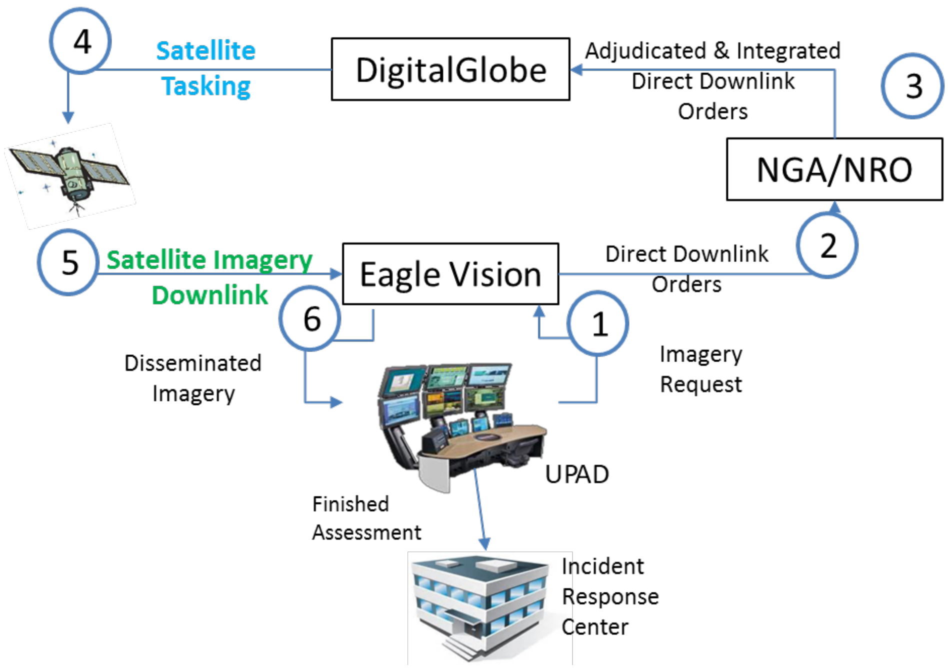


Figure 5-4. DigitalGlobe Architecture Option Three: WorldView DDL Only

C. Planet

Planet is a CSI provider headquartered in San Francisco, CA. The company is seven years old and employs approximately 400–450 people. In contrast to other CSI providers that can be described as "data brokers," Planet's business model is one in which the company does everything "in-house" aside from launching its satellites. Planet's in-house operations include designing satellites, manufacturing satellites, pre-launch testing of satellites, command and control of satellites on-orbit, and archiving and delivering calibrated, analysis-ready imagery to their customers.

Planet's mission statement, "… to image the entire Earth every day and make global change visible, accessible, and actionable," encapsulates the value of what Planet brings to the table: the ability to leverage an archive of daily images of the entire Earth's land mass to identify changes (man-made or natural), which can then be re-imaged at higher resolution, as necessary, using Planet's SkySat constellation. In order to carry out this mission, Planet currently operates 200 satellites as part of three constellations (see Figure 5-5). The operational mode of the PlanetScope constellation is that of a monitoring mission in which the sensors onboard the Dove satellites are always imaging at nadir, rather than receiving tasks to image specific targets. This is the same CONOPS used on the U.S. Government's Landsat satellites. Planet's SkySat constellation follows a traditional tasking model in which the satellites receive specific ground targets to image at specific times.

Planet is also a participant in the International Charter for Space and Major Disasters. The company provides access to PlanetScope imagery through HDDS at no cost for individuals and organizations directly involved in relief efforts. Users may access the entire archive of PlanetScope imagery within the disaster-affected area for a minimum of 30 days.

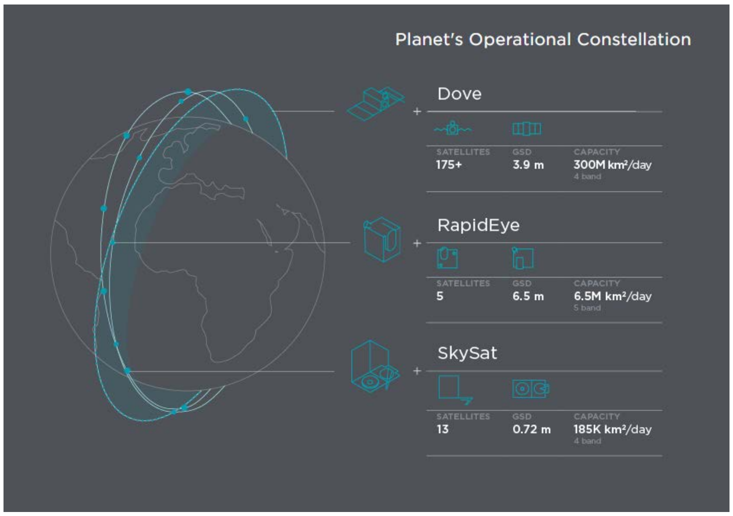


Figure 5-5. Summary of Planet's Three Satellite Constellations

1. Current Capabilities

As detailed in Table 5-3, Planet provides imagery at both EO and NIR wavelengths at resolutions ranging from 70 cm to 6.5 m GSD and with a daily revisit rate. For each constellation, there are multiple product lines available that offer analysis-ready images with varying levels of post-processing applied, such as calibration, cloud assessment, and orthorectification (see Figure 5-6).

Planet delivers imagery products to customers through a web browser or via an API. Customers log into their account on the "Explorer" portal to discover, preview, and download archived imagery. As designed, the graphical user interface (GUI) is a simple discovery and download tool: customers can download desired imagery, then import the imagery into their own tools for further analysis. The API can also automate discovery and download of large volumes of imagery. Users can download all Planet imagery products in the standard file formats NITF and GeoTIFF.

Table 5-3. Technical Specifications of Constellations and Sensors

CONSTELLATION	PlanetScope (Doves)	RapidEye	SkySat
NUMBER	175+	5	13 (8 more in production for Q1 2019 operation)
SIZE	CubeSat 3U form factor (10 cm × 10 cm × 30 cm)	Less than 1 cubic meter 150 kg	60 cm × 60 cm × 95 cm 110 kg
GSD (nadir)	3–4 meters (depending on flock)	6.5 meters	70–80 cm
GROUND COVERAGE	2 Frame sizes: 20 km × 12 km 24.6 km × 16.4 km	Swath width: 77 km	Scene size: 2560 × 1080 pixels
BANDS	Blue: 455–515 nm Green: 500–590 nm Red: 590–670 nm NIR: 780–860 nm	Blue: 440–510 nm Green: 520–590 nm Red: 630–685 nm Red edge: 690–730 nm NIR: 760–850 nm	Blue: 450–515 nm Green: 515–595 nm Red: 605–695 nm NIR: 740–900 nm Pan video: 450–900 nm
REVISITS	Daily at nadir for those in Sun-synchronous orbit	Daily (off-nadir) 5.5 days (at nadir)	4–5 days

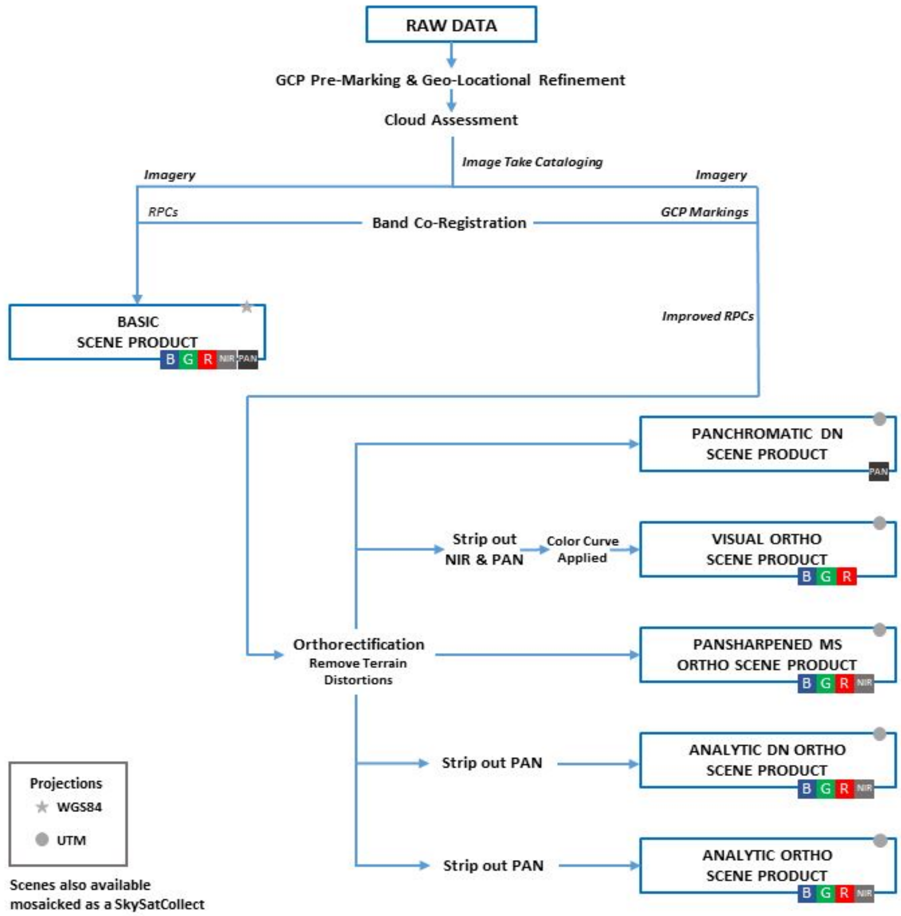


Figure 5-6. Image Processing Chain for SkySat Imagery

As of September 2018, Planet has also begun to offer a new "disaster subscription" plan with the goal of minimizing delays in imagery acquisition when timeliness is critical. Customers define a disaster type and geographic region of interest—for example, hurricane season and U.S. coastal regions along the Gulf of Mexico and Atlantic Ocean—well in advance of an event occurring. When the disaster takes place, Planet activates the pre-negotiated contract and grants the customer access to Planet's archive for imagery taken 30 days pre-disaster and 30 days post-disaster in the pre-defined geographic location.

2. Future Capabilities

Future capabilities for Planet fall into four categories: (1) improvements to the satellite constellations, (2) the development of tip-and-cue capability, (3) three dimensional mapping, and (4) web-based user tasking.

As of September 2018, Planet is able to build over 40 Dove satellites each week.[24] In addition, Planet is planning to manufacture and launch enhanced versions of the Dove satellites. The company expects that these ongoing additions to the PlanetScope constellation will afford better ground coverage, lower the time between revisits, and improve imagery analysis capabilities.

Planet also plans to launch an additional six SkySat satellites before the end of 2019, which would increase the total size of the SkySat constellation to 13 satellites. The company expects that the addition of these satellites would increase the already intra-daily revisit imaging capability of this constellation.

Planet stated that it is currently developing autonomous "tip-and-cue" capabilities based on spatial information feeds that monitor specific locations, including shipping lanes, ports, and railyards, to detect changes beyond a pre-determined threshold. As the satellite constellations grow and provide more passes per day in a given region, Planet's goal is to be able to perform the analysis between passes so that follow-up imaging at higher resolution using the SkySat constellation can take place as quickly as possible and ultimately automated using pre-defined tipping and cueing criteria.

The SkySat satellites have the ability to collect stereo-pairs, which allows the production of three-dimensional image products. Planet analysts and others can use this imagery create models of urban areas, for example, with building height accuracies of plus or minus one floor.

[24] Anna Escher, "Inside Planet Labs' new satellite manufacturing site," Tech Crunch, September 2018, https://techcrunch.com/2018/09/14/inside-planet-labs-new-satellite-manufacturing-site/.

Currently, customers communicate satellite tasking requests to Planet through email. Planet anticipates a 2018 release of an API for user tasking, eliminating the use of email, and streamlining the tasking process.

3. Possible Contract Options

Based on informal discussions, we describe below three generalized contract options for potential National Guard utilization of CSI provided by Planet:

Single Geography: In this arrangement, the customer would have ongoing and unlimited view-only access to Planet's imagery archive for a single terrestrial location. The National Guard would have a pre-determined download quota and would download only those images that they would plan to analyze with tools external to the Planet interface. This service, available through GSA, is tiered, based on the level of use the Government customer desires to support (Single Agency, Civil Federal, Intelligence Community/DoD Title 10/50, or All Federal agencies).

Multiple Geographies: This arrangement may be similar to the Single Geography option but expanded to include more than one area or for a pre-determined number of disasters.

On September 21, 2018, NGA awarded a $5.9M contract to Planet for this type of service. NGA's Planet Subscription contract provides new daily imagery over the U.S. Southern Command area of responsibility and areas of interest in the U.S. Africa Command and U.S. Indo-Pacific Command areas of responsibility. NGA did not award this contract through GSA but instead awarded an independent contract to Planet.

Daily Feed Subscription: Through GSA, Planet currently offers the U.S. Government subscriptions to its "Global Daily Feed," which includes all Dove imagery collected across the globe. Planet prices this service on the tiered model described above.

Fixed Price/All-You-Need: In this arrangement, for a fixed yearly (or multi-year) cost, the National Guard would have unlimited access to Planet's imagery archive without restriction on the number of disaster events, images downloaded, or number of geographic locations. In this model, there may be several contract years in which the National Guard would not utilize any Planet CSI and others in which the National Guard would consume a significant amount of Planet data. The National Guard would need to establish a direct contract with Planet for this service, as it is not yet available through GSA.

Planet encourages and facilitates pilot studies prior to contract finalization. Their Customer Success Teams provide virtual or in-person training and advanced technical support. The duration of the average pilot study is three to four months. Depending on the customer, the pilot study may be for a pre-determined number of disasters or events, rather than for a set amount of time.

D. BlackSky Global

BlackSky Global was founded in 2013 in Seattle, Washington, as a subsidiary of Spaceflight Industries. In 2016, Spaceflight Industries acquired OpenWhere, a company based in Herndon, Virginia, to develop a cloud-based geospatial intelligence platform for BlackSky Global. OpenWhere is now BlackSky Geospatial. The BlackSky Geospatial platform provides three primary functions:

- Monitoring and analysis of multiple open source data feeds—for example, from social media and news services—to tip and cue the potential need for new imagery collection over user-designated areas of interest based on user-selectable threshold criteria.
- Insight to recent imagery collection by multiple commercial and civil imaging satellite operators.
- The ability to order archived imagery or task new image collection across satellites operated by the above commercial operators, essentially functioning as a satellite imagery and data "GEOINT broker."

1. Current Capabilities

Today, the BlackSky platform integrates and offers customers on-demand access to satellite imagery from roughly 30 EO sensors, five SAR sensors, and seven weather sensors. Users can search a vast catalogue (see Figure 5-7) of CSI by geographic location, date taken, resolution, size, satellite (e.g., Pléiades-HR1A/1B, WorldView-1), and sensor angle; add images to their shopping cart; purchase the images; download in a variety of file formats; and track their budget and remaining funds for purchasing imagery in their user profile.

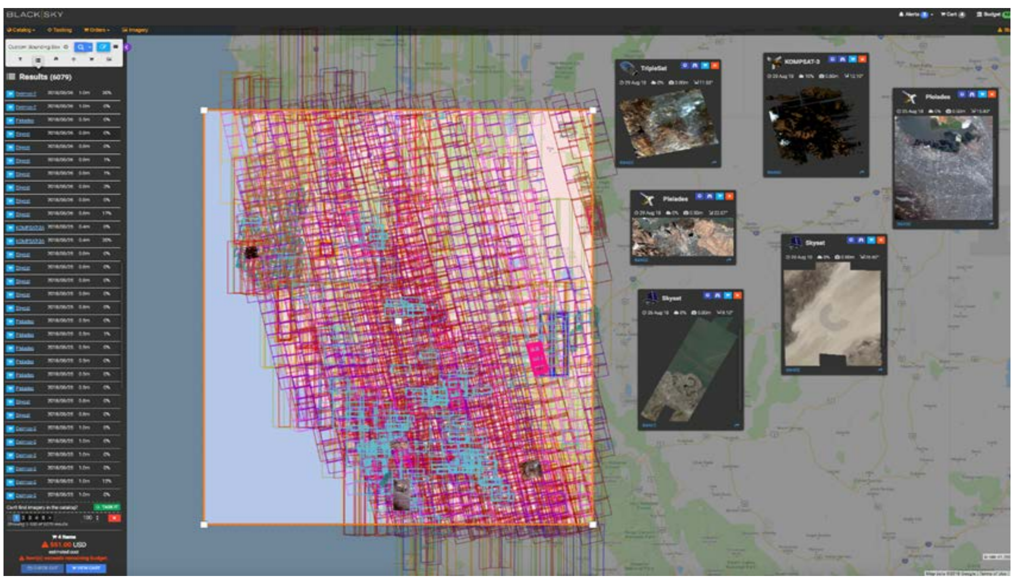


Figure 5-7. BlackSky Imagery Catalogue (Source: BlackSky)

Customers can also task many of the satellites in this collection through the BlackSky web interface, choosing specific sensors, desired resolutions, maximum cloud cover, and desired revisit rates, or select broader options such as “lowest cost,” “next available,” or “best resolution” (see Figure 5-8). BlackSky receives the tasking requests and works directly with the relevant CSI vendor to task the sensor the customer has requested. This “broker” approach offers the advantage of being able to access multiple satellite operators’ imagery through a single contract with BlackSky, rather than having a separate contract with each individual satellite operator.

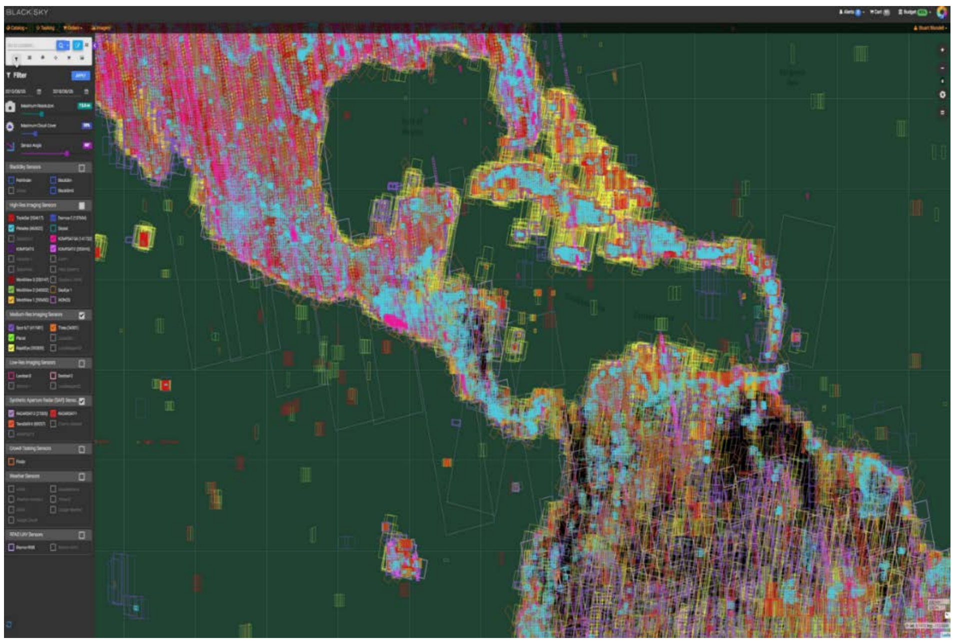


Figure 5-8. BlackSky Web-Based Tasking Interface (Source: BlackSky)

Once the provider has delivered the raw imagery to BlackSky, BlackSky can send the imagery to the requestor in a variety of web-delivery formats, such as email, Amazon Web Services, Google Drive, or Dropbox. BlackSky also supports downlink of imagery directly to customer-owned ground stations and does so for several international customers.

Unlike some other CSI vendors, BlackSky does not offer imagery analytics and tools on its platform. Customers receive processed imagery from BlackSky’s partner vendors for use in the customer’s own assessment environment.

In addition to CSI search and tasking functionalities, the BlackSky platform offers an online global event monitoring service that integrates satellite imagery from its diverse collection of sensors with information from local and regional news outlets, social media, and other data feeds to create customizable channels (see Figure 5-9). Users can build channels tailored to their specific interests and priorities—for example, certain geographic locations, ports, pipelines, geopolitical conflict, natural disasters, global health—and receive alerts on breaking news or critical events pertaining to their custom threads. The service links relevant imagery from BlackSky's archive to users' channels, so that customers can click on media reports and be automatically directed to CSI of potential interest.

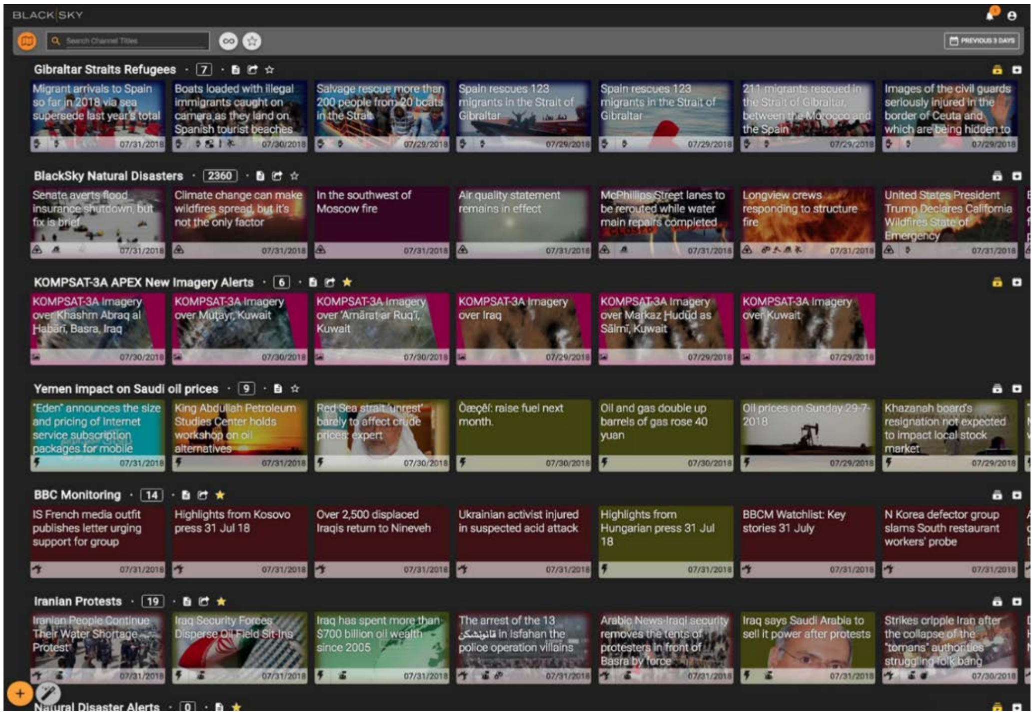


Figure 5-9. BlackSky Event Monitoring via Customizable Channels (Source: BlackSky)

NGA has maintained a multiyear contract with BlackSky to develop a tailored version of the BlackSky GEOINT broker platform, called the "Predictive GEOINT Pathfinder," which uses only the tipping and cueing and archive awareness functionality. In August 2017, the Air Force Research Laboratory announced that it had awarded BlackSky a two-year $16.4 million contract to develop a separate tailored version of the cloud-based GEOINT broker platform.[25]

2. Future Capabilities

Today, BlackSky acts solely as a data broker, but eventually its users will be able to task BlackSky's own Global satellites. By 2020, BlackSky plans to have a constellation of 60 55-kilogram EO satellites, called the Global series, in low Earth orbit. The company has completed development and construction of the first two satellites in the Global

[25] "BlackSky Awarded $16.4M Contract by Air Force Research Lab for Next-Generation Geospatial Intelligence Brokering Platform," BlackSky Global, August 28, 2017. https://www.blacksky.com/2017/08/28/blacksky-awarded-16-4m-contract-by-air-force-research-lab-for-next-generation-geospatial-intelligence-brokering-platform/

constellation and expects to launch them in November or December 2018. BlackSky announced that it would launch the first four satellites in the Global series over the course of the next year, or by March 2019. BlackSky has since purchased a SpaceX Falcon 9 to launch the satellites into orbit. The company is currently funded to complete the first 20 satellites in their 60 satellite constellation.

BlackSky's Global satellites are designed to provide 1 m GSD, four-band MSI for a three-year mission life at an altitude of 450 km above Earth's surface. BlackSky plans to use its constellation primarily for point target collection; a single frame is expected to be 4.5 km by 6 km (27 km^2). When complete, BlackSky anticipates that the satellites will provide point target rapid revisit rates across 95% of Earth's surface with the ability to pass over key zones hourly. BlackSky intends to be able to deliver images from the Global constellation to customers within one to two hours of collection through its online platform.

BlackSky representatives also said that the company is currently working on two upcoming features for its web interface: one will send users notifications about satellite imagery the platform detects they will likely be interested in seeing, and another will allow analysts to add annotations or commentary to the imagery in BlackSky's archive. The company plans to develop a mobile app version of its GEOINT platform, which it intends to build primarily for use on tablets.

3. Possible Contract Options

BlackSky suggested that if the National Guard is interested in accessing their services, the effort begin with an initial "trial run" implementation of its current platform services through a six- to nine-month pilot project, at an approximate cost of $500,000 to $750,000 for platform access and limited imagery purchases. BlackSky's operational base capability (access to the platform only) pricing schedule reflects Base, Professional, and Enterprise levels at approximate annual rates of $90K for five users, $400K for 25-250 users, and an amount in the low millions for 250–500 users. Final pricing would also need to include additional funding for imagery purchases from BlackSky's multiple imagery providers.

6. Summary of Findings

The IDA team developed a number of findings based on our review of the National Guard's IAA mission requirements, U.S. Government IAA resources, and current and emerging CSI capabilities, as well as our interviews with the National Guard, Eagle Vision, other government agencies, and commercial vendors. We summarize these findings below, offer several considerations for the National Guard, and evaluate options the NGB could pursue to use CSI to satisfy its IAA mission requirements:

- CSI can contribute significantly to satisfying National Guard IAA requirements for natural disasters, including requirements for situational awareness, damage assessment, LOC status, evacuation, and search and rescue.
- U.S. government space imaging assets such as Landsat, ASTER, and the GOES system are intended for scientific purposes and are not well suited to address natural disaster relief requirements, primarily due to the coarse resolution of their imagery.
- CSI from the International Charter for Space and Major Disasters is not available for all natural disasters. The USGS is selective about activating the Charter, typically doing so only for major natural disasters in the United States and particularly when SAR capabilities are needed to aid in response efforts. Once USGS activates the Charter, it often takes three to five days for HDDS to begin receiving imagery from commercial Charter members and partners.
- PAN and multispectral EO sensors with a resolution of 1.0 m GSD or better, responsiveness within 24 hours or less, and revisit times of 24 hours or less are required to satisfy most IAA mission needs. Higher resolution and responsiveness may be required for search and rescue, and lower resolution may be acceptable for gaining initial situational awareness. Imagery requirements can vary considerably, however, depending on specific circumstances and applications.
  - PAN and multispectral EO are the most widely applicable satellite imagery capabilities for natural disaster response efforts.
  - Imagery from airborne assets is preferred, and more effective, for supporting search and rescue missions, as aircraft flying at low altitudes are able to provide high resolution, as well as greater responsiveness and persistence.
- SAR can be valuable when weather conditions preclude the use of airborne assets, and when cloud cover associated with hurricanes or smoke associated with

wildfires or volcanic events obscure the disaster area. However, SAR imagery availability is limited to Eagle Vision (if funding permits) and contributions from the International Charter for Space and Natural Disasters. Airborne assets, when available, may also provide SAR imagery.

- The National Guard has limited extant capability to analyze SAR imagery. The required expertise currently resides within only the Air National Guard UPAD sites in Kansas, Indiana, Ohio, and Massachusetts.
- While SAR can image at night and under highly obscured atmospheric conditions, it does have limitations during certain extreme weather events. For example, during Hurricane Florence, National Guard imagery analysis teams reported that SAR imagery from TerraSAR-X and other sources were not usable due to smear caused by high-velocity, intense rains.
- Circularly polarized SAR imagery can overcome the above limitation, but most current commercial SAR platforms do not provide this capability. However, both traditional and emerging SAR satellite operators have incorporated circularly polarized SAR imaging into their future system designs.[26]

- Imagery provided through the EVFO and G-EGD contracts meets most IAA resolution, timeliness, and revisit rate requirements, but the National Guard may only access this imagery for natural disasters that prompt a presidential major disaster or emergency declaration. There are potential opportunities to optimize collection during other natural disaster situations within the scope of the existing contract.
- The business models of leading commercial vendors center largely on providing medium-to-high resolution broad area and global point target collection, with the former tipping and cueing the latter, followed by subsequent analysis of archived imagery and dissemination via a web-based architecture.
  - The combination of broad area coverage and rapid revisit by commercial satellite operators is producing rapidly growing commercial imagery archives that users can leverage for a wide range of purposes. As a result, companies are increasingly focusing on the development and application of analytic tools that can make use of those archives.
  - The commercial vendors interviewed by the IDA team viewed DDL primarily as a means to service non-U.S. defense and intelligence customers

[26] For example, RADARSAT and Airbus, as well as emerging companies Capella Space and ICEYE, have integrated circular polarization into their SAR system designs.

and maintained that web-based satellite tasking and imagery delivery can fully support unclassified imagery requirements.

- The National Guard also requires pre-disaster, same-season baseline imagery with sufficient resolution to facilitate more efficient and accurate and analysis. Optimally, such imagery would be collected on at least an annual basis and available to the National Guard days before the disaster, when an impending disaster can be anticipated.
- Delivery of EnhancedView imagery is sometimes delayed as a result of the time required for NRO and NGA to adjudicate individual imagery collection requests. NRO and NGA may not satisfy such collections requests, which compete with National Intelligence Priority Framework requirements.
- A well-established interagency process is already in place for using satellites to detect wildfires in the Western U.S.
- National Guard IAA collection management procedures appear to be ad hoc and took several days to become fully established during Hurricane Florence. IAA collection management could be examined further if desired by the National Guard.

A. Additional Considerations

This study raises the question of the extent to which the National Guard should be responsible for the provision of CSI to states and territories. Individual states and territories typically generate requirements during natural disasters and often address them within their authorities without Federal assistance. One could argue that states and territories should fund their own CSI requirements individually. However, CSI would be much more expensive if purchased on a small scale by multiple parties, and tasking and dissemination without a centralized coordination body would likely be less effective. The ability to coordinate CSI across several states is desirable, particularly for disasters that span state borders. FEMA may be in a position to perform such a coordinating function, but it can only intervene for disasters in which the state requests Federal assistance, and the U.S. Government approves the request. Many disasters do not reach this threshold. Given the restrictions on use of imagery provided through the EnhancedView contract for natural disasters limited to state and local response efforts, NRO and NGA are also not in a position to perform or resourced to provide a CSI coordinating function for all natural disasters.

Finally, the National Guard anticipates using CSI to provide humanitarian assistance and disaster relief (HADR) support to partner nations internationally in addition to supporting natural disaster relief efforts within the United States. Currently, the EVFO contract permits dissemination of EVFO DigitalGlobe imagery (as an example) to many foreign partner nations, but it restricts dissemination to certain countries. The National

Guard would need to conduct a review of the list of restricted nations and of other potential implications to HADR support should the National Guard establish a separate contract with a commercial provider.

7. Options for the National Guard

As our findings demonstrate, there are benefits and disadvantages associated with each of the existing CSI sources the National Guard uses today, and the same is true for other CSI options the National Guard could leverage. After examining the U.S. Government and commercial imagery sources currently available to the National Guard, as well as additional industry CSI capabilities, the IDA team finds that the National Guard has three broad options to leverage CSI to support the IAA mission. These options are not mutually exclusive; rather, the National Guard could choose any combination of these approaches:

1. **Maintain the status quo**. With this option, the National Guard would retain access to CSI from Eagle Vision in all natural disaster situations, access to CSI from DigitalGlobe in the event that the President issues a major disaster or emergency declaration, and access to additional CSI when USGS activates the International Charter.
2. **Seek expanded utilization of the EVFO and G-EGD contracts.** This option would entail the National Guard exploring ways to gain greater access to the CSI capabilities provided by the existing NRO and NGA contracts with DigitalGlobe in addition to imagery that becomes available subsequent to a presidential major disaster or emergency declaration.
3. **Establish a separate contract with a vendor for CSI**. With this option, the National Guard would select a specific provider and develop a contract for desired CSI capabilities.

Below, we summarize the advantages and limitations of these options, evaluating them based on the responsiveness of the current or potential CSI capability, the quality of the capability, and whether there are restrictions on disseminating or sharing the imagery. We also consider the potential feasibility of each option.

1. Maintain the Status Quo

The National Guard could retain Eagle Vision as its primary provider of unclassified CSI. Eagle Vision can be responsive prior to and during a natural disaster. Its ground stations can downlink and disseminate imagery through EVR2EST quickly in most cases.

The ability to share Eagle Vision CSI to an unlimited extent with any and all mission partners, including with partner nations for overseas HADR missions, is a notable benefit of the Eagle Vision program. Other benefits are Eagle Vision's authority to develop its own tasking and collection schedule directly with Airbus satellite operators, and its ability to operate independently of the NRO and NGA prioritization process for addressing CSI requests from outside organizations.

Through its current contract, Eagle Vision can supply only a limited volume of high-resolution EO and SAR imagery. The operation and maintenance costs of Eagle Vision are significant, and integration of any additional satellites into the program's portfolio would necessitate upgrades to each of the ground stations and operator training at additional cost.

2. Seek Expanded Utilization of the EVFO Contract

The National Guard could seek modifications to its ability to access imagery under the existing EnhancedView contract, potentially at little to no additional cost. Such modifications would grant the National Guard increased access to high-resolution, broad area DigitalGlobe CSI to satisfy IAA mission requirements.

DigitalGlobe representatives expressed to the IDA team that they would be amenable to developing a natural disaster imagery collection plan using unutilized collection capacity over the United States. This collection plan would take effect in the event of a natural disaster, for example, prior to hurricane landfall. The National Guard could receive the imagery through DigitalGlobe's EnhancedView WHS or through downlink to Eagle Vision ground stations. The latter delivery method would require additional upgrades to systems at NRO, NGA, and DigitalGlobe. This arrangement could also be highly responsive, because it would not require adjudication between multiple point targets and likely would not compete significantly with National Intelligence Priority Framework targets. Although NGA anticipates that commercial SAR capabilities will be available in the future, the timing is uncertain and will likely require a separate contractual agreements in the medium-to-long term.

NGA indicated that it is considering similar CONOPS in support of natural disaster response that could provide wide latitude to DigitalGlobe for associated CSI collection similar to the concept outlined above.

3. Establish a Separate Contract with a Commercial Vendor

Other alternatives would require the establishment of a contract (or contracts) between the National Guard and one or more CSI providers. The vendors we interviewed each offer compelling capabilities. DigitalGlobe offers the ability to task high-resolution sensors that have intra-daily revisit rates that will increase as the company launches its new WorldView Legion constellation. DigitalGlobe is also the most well-established of the vendors, having had a relationship with NGA for many years. Planet offers medium-resolution imagery, imaging of the entire Earth's surface daily, and the ability to task high-resolution satellites separately. BlackSky provides a unique, user-friendly, and tailorable tasking interface that grants access to a wide range of commercial constellations with varying resolutions, revisit rates, and pricing options. It also offers customizable, topical channels of information from news and social media for tipping and cueing to specific imagery and mission needs, which the National Guard has found valuable in recent responses to natural disasters.

Again, the National Guard would need to address dissemination abilities with each vendor, including anticipated HADR requirements in support of partner nations in the future. Unlike a scenario in which the Guard would leverage the existing EVFO and G-EGD contracts, establishing independent contracts directly with CSI vendors would require additional National Guard resources.

8. Conclusions

In the event of a natural disaster in the United States, the National Guard needs to be able to integrate IAA capabilities to satisfy incident commander information requirements and support missions such as situational awareness, damage assessment, search and rescue, and evacuation. The IDA team's survey of various CSI options found that commercial satellite capabilities would be able to support the National Guard's mission.

High-resolution PAN and multispectral EO with broad area coverage can satisfy National Guard requirements for situational awareness during the initial days following a disaster, inform subsequent damage assessment, and support ingress into and evacuation out of the affected area. CSI can also assist in search and rescue, although aircraft-acquired imagery provides greater utility when available.

SAR commercial imagery has utility for cloud-covered conditions that often occur in conjunction with hurricanes, wildfires, or volcanic eruption, but it is not yet as readily available as EO CSI. As a result, the requirement for SAR imagery is often a driver for activation of the International Charter for Space and Natural Disasters by the USGS. However, the analysis of SAR requires expertise that is limited in the National Guard, and SAR imagery may provide little utility during periods of intense rain, as was the case for the first days of Hurricane Florence.

The National Guard utilizes satellite imagery primarily from Eagle Vision, U.S. Government and international sources provided through the USGS HDDS repository, and DigitalGlobe through the NRO EVFO and NGA G-EGD contracts. Of the CSI resources surveyed, EO CSI obtained through G-EGD provides the highest resolution and most extensive coverage. Most of the sensors that populate the USGS repository, such as Landsat, are intended for scientific broad area mapping missions, and their resolutions, responsiveness, and revisit times are not well suited for natural disaster relief. Pléiades imagery collected by Eagle Vision provides excellent resolution but availability is limited due to funding constraints. Funding constraints likewise limit the availability of Eagle Vision-provided TerraSAR-X and TanDEM-X imagery.

DigitalGlobe and Planet, the two leading U.S. CSI companies, are both capable of broad area coverage and point target collection. Both companies archive downlinked imagery into extensive repositories, which users can access through web-based user interfaces. DigitalGlobe's archive contains over 16 years of the highest-resolution CSI, with broad coverage over much of the globe. Planet's repository is not as extensive, as their Dove constellation did not reach full operations until recently. DigitalGlobe's current constellation is capable of imaging the Earth's entire land area several times per year as well as high volume point target collection with intra-daily frequency. Planet, conversely, has launched two constellations, each with very different capabilities. Planet's Dove constellation collects medium-resolution imagery of the Earth's entire land area a single time each day. The SkySat constellation can collect point targets, video, and small areas multiple times each day. BlackSky Global also plans to focus on intra-daily point target collection for its future constellation of one meter resolution satellites.

In general, CSI operators are shifting their capabilities from simple, systematic, large-area collection to large-area collection coupled with higher-resolution and frequency point target collection. The CSI industry is focused on developing capabilities to tip and cue point target collection based on changes detected in broad area imagery and or in open sources, such as social media and news feeds. These companies and, in some cases, their value-added resellers are also developing and fielding automated imagery analysis tools, but in general they do not yet have mature capabilities. Most of the companies the IDA team surveyed used DDL primarily to deliver imagery to international customers. Only two of the companies, Airbus and BlackSky, provided access to SAR in addition to EO sensors.

The IDA team recommends that the National Guard leverage the EVFO and G-EGD contracts to the extent possible to improve natural disaster support by engaging NRO and NGA directly in collaboration with like-minded organizations such as FEMA, USGS, the U.S. Forest Service, and others. The specific recommendations are as follows:

- The National Guard should advocate for a CONOPS optimized for standing imagery collection in support of natural disaster response. This approach could significantly improve collection for natural disasters by taking advantage of reduced demand and excess sensor capacity over CONUS, and by providing commercial vendors wider latitude, when appropriate, to task collections in anticipation of future U.S. Government requirements. Such a CONOPS could maximize relevant coverage, improve responsiveness, and reduce tasking adjudication delays and complexities.
- The National Guard should engage the NGA General Counsel to explore the potential to broaden access to EnhancedView imagery to include Title 32 authorities outside of presidentially declared natural disasters.
- The National Guard should advocate for increased availability of SAR capabilities to Title 32 authorities.

Appendix A. Case Study: The National Guard UPAD Response to Hurricane Florence

IDA was a “fly-on-the-wall” participant in the NGB J2 Hurricane Florence UPAD coordination calls held daily from September 14 to 25, 2018. Our goal was to understand the NGB J2 and UPADs’ IAA mission in response to the hurricane, including imagery collection and dissemination, the UPAD stand-up and tasking process, and overall coordination efforts. This section summarizes our observations and subsequent analysis of relevant data pulled from DAART.

1. Satellite Imagery was a Small Fraction of the Data Processed by National Guard UPADs

Findings: The majority (approximately 57%) of data processed by the UPADs in support of Florence came from aerial assets: RC-26, CAP Cessna 172 and Cessna 182 aircraft, NOAA Gulfstream and King Air 350 aircraft, Raven, WAMI (wide area motion imagery), and UH-72. Satellite imagery obtained in direct response to Florence (e.g., SAR) and processed by the UPADs was approximately 3% of the total. Satellite imagery the UPADs used, but whose original collection was not in direct response to Florence (e.g., Google Maps), was approximately 19%.

In Table A-1 below, we show the breakdown of information processed by the UPADs in support of the NGB’s Florence efforts.

Table A-1. Sources of Information Processed by National Guard UPADs

Source of Information	Total Collections	Notes
Ground Assets	**11**	
River Web Cam	1	
NC DOT	6	North Carolina Dept. of Transportation
SC DOT	4	South Carolina Dept. of Transportation
Aerial Assets	**395**	
CAP	67	
UH-72	5	(helicopter)
NOAA	39	Includes: NOAA / NOAA Aerial / NOAA Imagery
Raven	17	(hand-launched UAV)
RC-26	257	
WAMI	10	(Wide Area Motion Imagery)
Space Assets	**20**	
SAR	4	Includes: PALSAR-2 / SAR

Source of Information	Total Collections	Notes
PAN	1	
Satellite	3	Includes: SAT / Satellite
Digital Globe	10	
World View	2	
Web-Based Imagery Assets	**130**	
HDDS	1	
GIS	30	Includes: GIS / Esri
Google Products	99	Includes: Google Earth, Google Maps
Web-Based Model/Prediction/Reporting Assets	**24**	
FIMAN	14	(Flood Inundation Mapping and Alert Network)
Flood.nc.gov	1	
FRIS.NC.gov	6	(Flood Risk Information System)
NWM	1	(National Water Model)
poweroutage.us	2	
Human Assets	**80**	
DATAMINR	31	
HUMINT (local residents)	1	
Twitter	48	
Government	**7**	
FEMA	4	
National Weather Service	1	
SC Emergency SPINS	2	Special Instructions
Generic/Unspecified	**29**	Includes: Imagery / Multiple / Open Source / PAI

1. Data collected from the following files downloaded from DAART (with duplicate entries removed):
   - 18_Sep_18_Collection_Products.xlsx
   - 19_Sep_18_Collection_Products.xlsx
   - 21_Sep_18_Collection_Products.xlsx
   - Collection_products and hours worked for NGB cao 23SEP18 IN.xlsx
   - Collection_products_KS.xlsx
   - Collection_products CAO2200EST 25 Sep KS.xlsx
2. UPADs included: AR, IN, KS, NM, OH

Table A-2 shows the relative contribution of each type of data source. As seen in Table A-1, the top five sources of data were the RC-26 (257 collections), Google Maps/Earth (99 collections), CAP (67 collections), Twitter (48 collections), and NOAA (39 collections).

Table A-2. Relative Contribution of Data Sources

Source	Total "collections" (#)	Percentage (%)
Aerial Assets	395	56.8
Web-Based Imagery Assets	130	18.7
Human Assets	80	11.5
Web-Based Model/Prediction/Reporting Assets	24	3.4
Space Assets	20	2.9
Ground Assets	11	1.6
Government	7	1.0
Generic/Unspecified	*29*	*4.2*

1. Data collected from the following files downloaded from DAART (with duplicate entries removed):
   18_Sep_18_Collection_Products.xlsx
   19_Sep_18_Collection_Products.xlsx
   21_Sep_18_Collection_Products.xlsx
   Collection_products and hours worked for NGB cao 23SEP18 IN.xlsx
   Collection_products_KS.xlsx
   Collection_products CAO2200EST 25 Sep KS.xlsx
2. UPADs included: AR, IN, KS, NM, OH

The reliance on aerial assets stands out in Table A-2: almost 60% of all the data processed by the UPADs came from aircraft. This characteristic also appears in Figure A-1. In Figure A-1 below, we show the number of collections processed by the UPADs broken down by category as a function of time. Between September 17 and 23, 2018, aerial assets provided a minimum of 57% and a maximum of 84% of the daily totals of information processed.

Discussion: These findings raise the question of why satellite imagery (both commercial and government) was not utilized to a greater extent. Was the emphasis on aircraft because:

1. Collection managers were unfamiliar with available satellites assets and related procedures for retrieving and analyzing the imagery?
2. Aircraft were more responsive and useful than satellite imagery?
3. Collection managers were unaware that government and commercial satellite imagery was available?
4. Collection managers were aware of satellite imagery availability, but lacked institutional knowledge of how to request or access the imagery?
5. Collection managers/the UPADs were aware of and accessed satellite imagery, but the quality of the imagery was insufficient to satisfy requirements?

The answers to these questions are important to assessing the utility of CSI to the National Guard for its IAA capabilities. A separate but related question, which is beyond the scope of the current study, is "What is the aggregated cost of aerial imagery compared to CSI?"

2. ***Most UPAD Activity Came After Landfall***

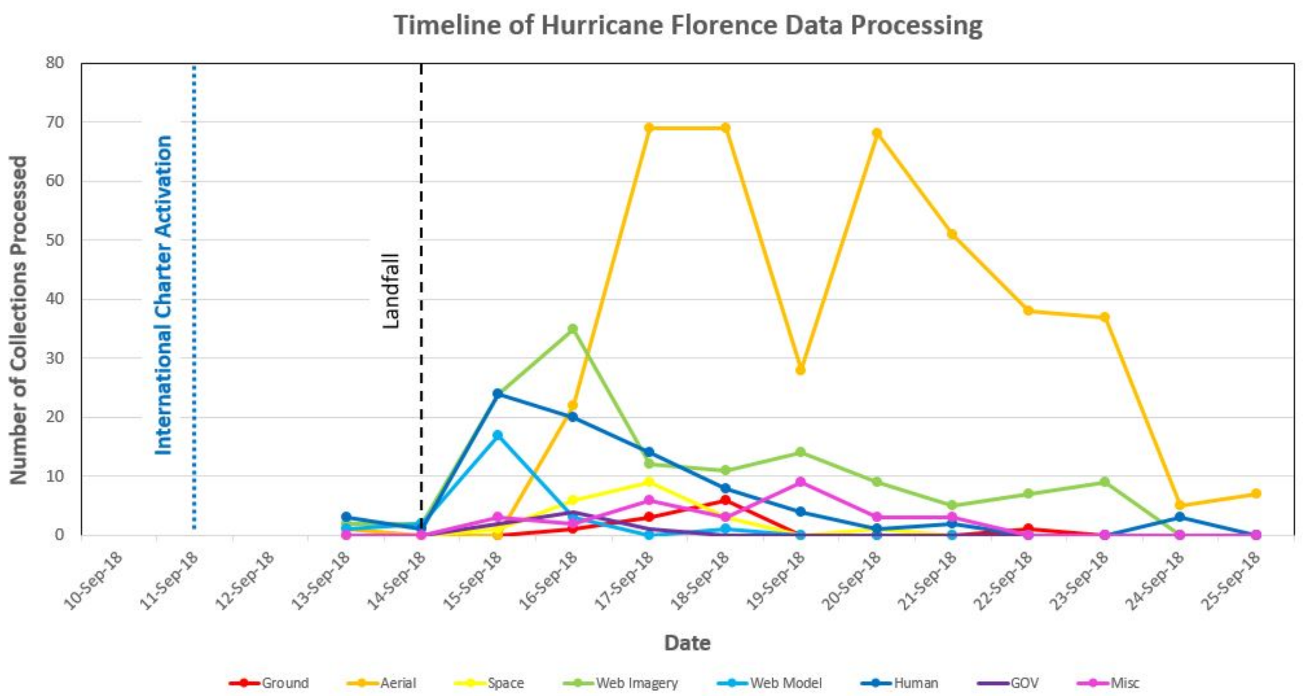


Figure A-1. Timeline of Hurricane Florence Data Processing

USGS activated the International Charter for Space and Major Disasters on September 11, 2018 and the hurricane made landfall on September 14, 2018. Processing of non-aerial collections by the UPADs began one day prior to landfall and peaked two to three days after landfall. Aerial collections began two days after landfall and dominated the UPAD workload until the end of operations (September 25, 2018).

Findings: In Figure A-1, we show the number of collections processed by the Arkansas, Indiana, Kansas, New Mexico, and Ohio UPADs broken down by category as a function of time. Two important dates are marked: the activation of the International Charter for Space and Major Disasters (the Charter) on September 11, 2018, and the landfall of Hurricane Florence on September 14, 2018. The UPADs did not begin processing information until two days after USGS activated the International Charter and one day before landfall. Substantial collections did not occur until one day after landfall (September 15, 2018). Two days after landfall (September 16, 2018), the first RC-26 flew and the first SAR imagery was processed. If the collections and processing of aerial asset imagery are set aside, September 15 and 16, 2018 were the busiest days for the UPADs; there is a steady decline in the processing of non-aerial collections starting three days after landfall. In contrast, the UPADs processed aerial collections at a nearly steady and significant rate for the time period between two and nine days after landfall.

3. SAR Analysis

Findings: Unlike EO PAN systems, SAR can see through cloud cover. In this regard, it is very useful during weather-related events such as hurricanes when flooding is imminent or in progress, but rain and wind conditions prevent aircraft from flying below the cloud deck. SAR can be collected from both satellites and aircraft. Examples of both can be found in the DAART archives and are discussed here.

Figure A-2, produced by the Ohio UPAD, demonstrates how SAR collected from a satellite was useful two days after the landfall of Hurricane Florence in determining flooding at a coal ash pond in North Carolina. In discussions with the Ohio UPAD after Florence operations ceased, the Ohio UPAD emphasized the utility of SAR data, particularly when used in conjunction with publicly available information (PAI).

There were only four instances of the UPADs processing SAR data during Florence (see Table A-1). According to the Ohio UPAD, there were two main reasons for this:

1. SAR was sometimes collected in the wrong location and/or at the wrong time, and
2. NASA's Gulfstream aircraft collected by far the most SAR data, but the file format was different than what the UPAD analysts were familiar with, thus they did not feel confident in their ability to properly analyze it.

The Ohio UPAD also noted that they acquired some TerraSAR-X imagery from Eagle Vision via EVR2EST, but, due to EVR2EST server crashes and broken or missing file links, they relied most heavily on TerraSAR-X data that appeared on HDDS as a result of the International Charter activation.

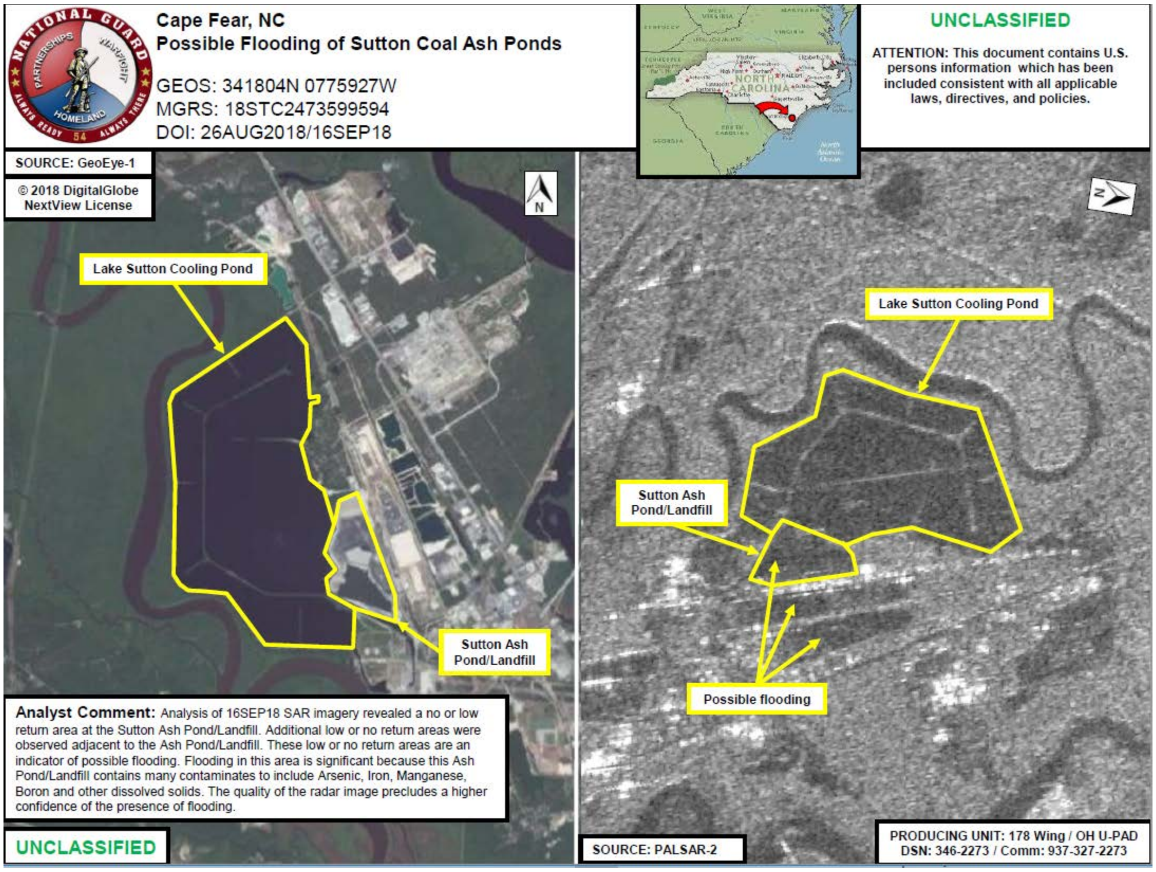


Figure A-2. PALSAR-2 Imagery from Hurricane Florence Response

Imagery analyzed by the Ohio UPAD showing possible flooding at a coal ash pond in North Carolina. The SAR imagery was captured two days after the landfall of Hurricane Florence when cloud cover and unfavorable atmospheric conditions prevented the acquisition of imagery from satellites and/or aircraft.

Discussion: As noted by the Ohio UPAD, NASA's Gulfstream produced a wealth of SAR imagery during Hurricane Florence, but only NASA's own analysts could analyze it with confidence. The Ohio UPAD indicated that it has reached out to NASA to request training on how to use the Gulfstream data so that they are better prepared for future natural disasters.

4. *Collection Management*

Findings: There does not appear to be an established, formalized framework for interagency coordination on imagery and collection management. Leadership among various agencies (e.g., NGB, FEMA, state government, NASA) coordinate with each other with regard to imagery collection so as to not duplicate efforts, but this coordination appears to be an ad hoc activity.

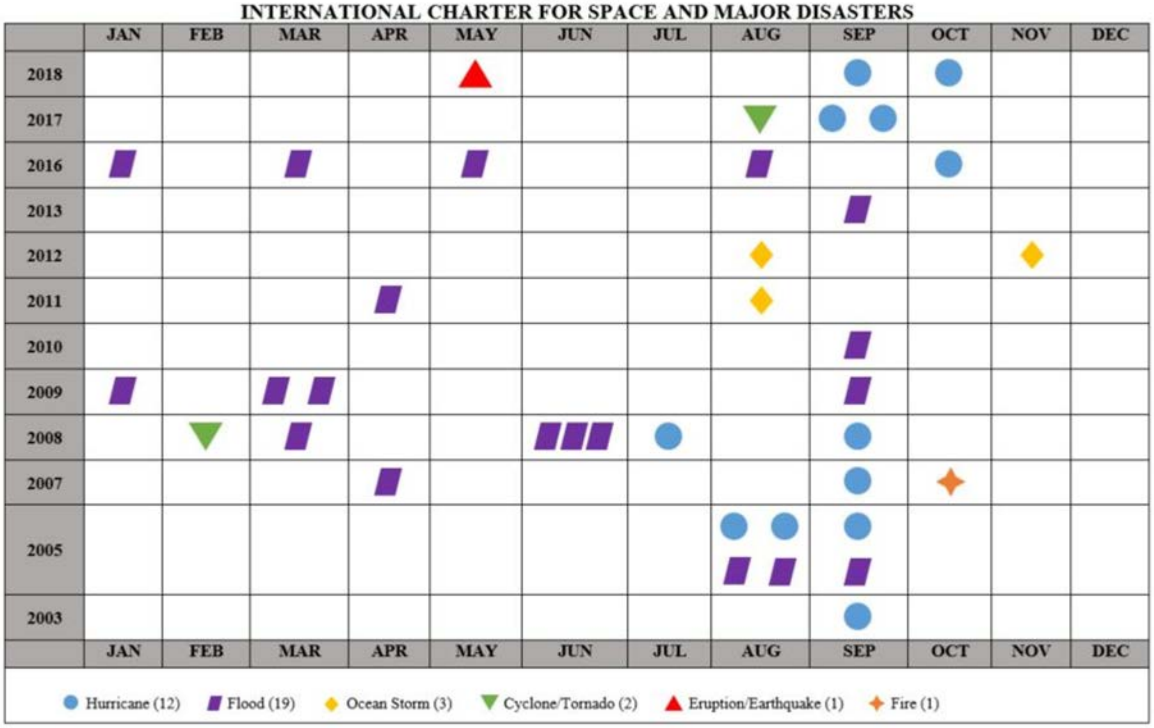
Appendix B. U.S. International Charter Activations and Charter Members and Partners

DOMESTIC ACTIVATIONS OF THE INTERNATIONAL CHARTER FOR SPACE AND MAJOR DISASTERS

EVENT	ACTIVATION DATE	CHARTER REQUESTOR
2018		
Hurricane Michael	10 OCT	USGS on behalf of FEMA
Hurricane Florence	11 SEP	USGS on behalf of FEMA
Earthquake and Eruption of Kilauea Volcano	07 MAY	USGS on behalf of USGS Hawaii Volcano Observatory / Cascades Volcano Observatory
2017		
Hurricane Maria	19 SEP	USGS on behalf of FEMA
Hurricane Irma	06 SEP	USGS on behalf of FEMA
Cyclone (TX)	24 AUG	USGS on behalf of Governor's Texas Emergency Management Council including the Texas Division of Emergency Management
2016		
Hurricane Matthew	06 OCT	USGS on behalf of FEMA
Flood (LA)	13 AUG	USGS on behalf of State of Louisiana
Flood (TX)	31 MAY	USGS on behalf of Texas Emergency Management
Flood	11 MAR	USGS on behalf of FEMA
Flood	03 JAN	USGS on behalf of FEMA
2013		
Flood (CO)	13 SEP	USGS on behalf of NGB/State of Colorado
2012		
Ocean Storm (NY, NJ)	01 NOV	USGS on behalf of FEMA
Ocean Storm (Gulf Coast)	31 AUG	USGS on behalf of FEMA
2011		
Ocean Storm (East Coast)	27 AUG	USGS on behalf of FEMA
Flood (Central Midwest)	28 APR	USGS on behalf of US Corps of Engineers, States of Missouri and Illinois
2010		
Flood (WI)	24 SEP	USGS on behalf of Wisconsin Emergency Management
2009		
Flood (GA)	22 SEP	USGS on behalf of Georgia Emergency Management
Flood (ND)	25 MAR	USGS on behalf of North Dakota
Flood (IN)	11 MAR	USGS on behalf of State of Indiana
Flood (WA)	09 JAN	USGS on behalf of FEMA
2008		
Hurricane Ike	12 SEP	USGS on behalf of State of Texas
Hurricane Gustav	01 SEP	USGS on behalf of State of Louisiana
Hurricane Dolly	23 JUL	USGS on behalf of State of Texas
Flood (IA)	12 JUN	USGS on behalf of State of Iowa
Flood (IN)	10 JUN	USGS
Flood (WI)	10 JUN	USGS

EVENT	ACTIVATION DATE	CHARTER REQUESTOR
Flood (AR, IL, IN, KY, MI, OH, TX)	20 MAR	USGS
Tornadoes (KY, TN, AL, MS, AR)	08 FEB	USGS
2007		
Fires (CA)	23 OCT	USGS
Flood (NY)	17 APR	USGS
2005		
Hurricane Katrina + Flood	02 SEP	French Civil Protection
Hurricane Katrina + Flood	31 AUG	USGS
Hurricane Katrina + Flood	27 AUG	USGS, French Civil Protection
2003		
Hurricane Isabel	25 SEP	NOAA
Data taken from https://disasterscharter.org/web/guest/charter-activations		

DOMESTIC ACTIVATIONS
OF THE
INTERNATIONAL CHARTER FOR SPACE AND MAJOR DISASTERS



International Charter for Space and Major Disasters: Members and Partners
Charter Members
Agencia Bolivariana para Actividades Espaciales (ABAE)
Canadian Space Agency (CSA)
Centre National d'Etudes Spatiales (CNES)
China National Space Administration (CNSA)
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
European Space Agency (ESA)
German Aerospace Center (DLR)
Indian Space Research Organisation (ISRO)
Japan Aerospace Exploration Agency (JAXA)
Korea Aerospace Research Institute (KARI)
National Institute for Space Research (INPE)
National Oceanic and Atmospheric Administration (NOAA)
The Argentine Space Agency (CONAE)
The State Space Corporation (ROSCOSMOS)
UAE Space Agency (UAESA) and Mohammed Bin Rashid Space Centre (MBRSC)
UK Space Agency and DMC International Imaging (DMCii)
United States Geological Survey (USGS)
Charter Partners
Airbus Defence and Space
Algerian Space Agency (ASAL)
Asian Disaster Reduction Center (ADRC)
Committee on Earth Observation Satellites (CEOS)
Copernicus
DigitalGlobe
DMCii
European Union Satellite Centre (SatCen)
Group on Earth Observations (GEO)
MDA
Mohammed Bin Rashid Space Centre (MBRSC)
National Space Organisation of Taiwan (NSPO)
National Space Research and Development Agency (NASRDA)
Planet
Satellite Imaging Corp.
Sentinel Asia
Tübitak-BILTEN
UNITAR's Operational Satellite Applications Programme (UNOSAT)
United Nations Office for Outer Space Affairs (UNOOSA)

International Charter Members are space agencies and space system operators who work to provide satellite imagery for disaster monitoring purposes. Charter Partners provide disaster monitoring services for specific regions of the world and work with the Charter to further the distribution of data to the end users; contribute additional satellite data for use in monitoring disasters; and produce maps based on satellite data for use in interpreting and assessing disaster situations.[27]

[27] "About the Charter," International Charter for Space and Major Disasters, https://disasterscharter.org/web/guest/about-the-charter.

Appendix C. CSI Reference Guide for Natural Disasters

Commercial Satellite Imagery Reference Guide for Natural Disasters*

	Spatial Resolution Requirements		Airbus†			DigitalGlobe					Planet		
	Task	GSD	SPOT 6/7 PAN: 1.5 m MSI: 6 m	Pleiades PAN: 0.5 m MSI: 2 m	TerraSAR‡ SAR fine: 0.6 m SAR coarse: 40 m	GeoEye-1 PAN: 0.46 m MSI: 1.84 m	WorldView-1 PAN: 0.5 m MSI: N/A	WorldView-2 PAN: 0.46 m MSI: 1.84 m	WorldView 3 & 4 PAN: 0.31 m MSI: 1.24 m	RADARSAT-1 SAR fine: 3 m SAR coarse: 100 m	PlanetScope PAN: N/A MSI: 3-4 m	RapidEye PAN: N/A MSI: 6.5 m	SkySat PAN: 0.72-0.86 m MSI: 1 m
Situational Awareness	Ash Cloud Monitoring	1 km	✓	✓	✓	✓	✓	✓	✓	✓			✓
			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Mapping Lava Flows	10 – 30 m	✓	✓	✓	✓	✓	✓	✓	✓			✓
			✓	✓	×	✓		✓	✓	×	✓	✓	✓
	Fire Detection & Monitoring	250 m	✓	✓	✓	✓	✓	✓	✓	✓			✓
			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Local Burned Area Assessment	5 m	✓	✓	✓	✓	✓	✓	✓	✓			✓
			×	✓	×	✓		✓	✓	×	✓	×	✓
	Measuring Flood Peak	30 m	✓	✓	✓	✓	✓	✓	✓	✓			✓
			✓	✓	×	✓		✓	✓	×	✓	✓	✓
	Fire Fuel Mapping	5 – 30 m	✓	✓	✓	✓	✓	✓	✓	✓			✓
			O	✓	×	✓		✓	✓	×	✓	O	✓
Damage Assessment	Flood Damage	2 – 5 m	✓	✓	✓	✓	✓	✓	✓	O			✓
			×	✓	×	✓		✓	✓	×	O	×	✓
	Rooftop Damage	1 – 1.5 m	O	✓	✓	✓	✓	✓	✓	×			✓
			×	×	×	×		×	O	×	×	×	✓
	Damage to Individual Roof Rafters	0.2 – 0.6 m	×	O	O	O	O	O	O	×			×
			×	×	×	×		×	×	×	×	×	×
	Windstorm Damage Detection	1 m	×	✓	✓	✓	✓	✓	✓	×			✓
			×	×	×	×		×	×	×	×	×	✓
	Earthquake Damage Assessment	0.6 – 1 m	×	✓	✓	✓	✓	✓	✓	×			O
			×	×	×	×		×	×	×	×	×	O
Search & Rescue	Location of Trapped People	0.5 m	×	✓	×	✓	✓	✓	✓	×			×
			×	×	×	×		×	×	×	×	×	×
	Helo Landing Zone	0.5 m	×	✓	×	✓	✓	✓	✓	×			×
			×	×	×	×		×	×	×	×	×	×
Evacuation	Ingress/Evac Routes	1 m	×	✓	✓	✓	✓	✓	✓	×			✓
			×	×	×	×		×	×	×	×	×	✓
	Evacuation Obstructions	< 1 m	×	O	O	O	O	O	O	×			O
			×	×	×	×		×	×	×	×	×	×

Key:

✓	System provides the desired resolution	
O	System provides only a portion of the desired resolution	
×	System does not provide the desired resolution	
	EO Sensors	SAR Sensors**
TASK	PAN capability	Fine: spotlight mode
	MSI capability	Coarse: low resolution/wide scan mode
** Listed SAR resolutions are range resolutions; azimuthal resolution may be finer.		

Notes

*: Information current as of NOV 2018. Additional resources are available via BlackSky Global who currently brokers access to roughly 30 EO sensors, 5 SAR sensors, and 7 weather sensors.

†: More satellites could be made available via brokered services.

‡: TanDEM-X, the twin of TerraSAR, is also available.

Acronyms and Abbreviations

API	Applications Programmer Interface
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CAC	Common Access Card
CAP	Civil Air Patrol
CIBORG	Commercial Initiative to Buy Operationally Responsive GEOINT
CE90	Circular Error at 90 Percent Probability
CONOPS	Concept of Operations
CONUS	Continental United States
CSI	Commercial Satellite Imagery
DAART	Domestic Operations Awareness and Assessment Response Tool
DCGS	Distributed Common Ground System
DDL	Direct Downlink
DHS	Department of Homeland Security
DoD	Department of Defense
DMC	Disaster Monitoring Constellation
DSCA	Defense Support of Civil Authorities
EO	Electro Optical
EROS	Earth Resources Observation and Science
EVFO	EnhancedView Follow-On
EVR2EST	Eagle Vision & ROVER Responsive Exploitation of Space Products for Tactical Use
EXORD	Execute Order
FEMA	Federal Emergency Management Agency
FMV	Full Motion Video
GBDX	Geospatial Big Data Platform
G-EGD	Global Enhanced GEOINT Delivery
GEOINT	Geospatial Intelligence
GeoTIFF	Geo Tagged Image File Format
GIS	Geospatial Information Systems
GOES	Geostationary Operational Environmental Satellite
GRD	Ground Resolved Distance
GSA	General Services Administration

GSD	Ground Sample Distance
GUI	Graphical User Interface
HADR	Humanitarian Assistance and Disaster Relief
HAF	Headquarters, Air Force
HAF A2	Headquarters, Air Force Intelligence, Surveillance and Reconnaissance Directorate
HDDS	Hazards Data Distribution System
HSI	Hyperspectral Imagery
IAA	Incident Awareness and Assessment
IDA	Institute for Defense Analyses
IR	Infrared
ISR	Intelligence, Surveillance, and Reconnaissance
ISRG	Intelligence, Surveillance, and Reconnaissance Group
LE90	Linear Error at 90 Percent Probability
LOC	Line of Communication
MDA	MacDonald, Dettwiler and Associates
MSI	Multispectral Imagery
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NGB	National Guard Bureau
NGB A2/3/6/10	National Guard Bureau Operations Directorate
NGB J2	National Guard Bureau Intelligence Directorate
NITF	National Imagery Transmission Format
NIIRS	National Imagery Interpretability Scale
NIR	Near-Infrared
NOAA	National Oceanic and Atmospheric Administration
NRO	National Reconnaissance Office
PAI	Publicly Available Information
PAN	Panchromatic
SAR	Synthetic Aperture Radar
SAW	Satellite Access Window
SETA	Systems Engineering and Technical Assistance
SWIR	Short-Wave Infrared
UPAD	Unclassified Processing, Assessment, and Dissemination
USGS	United States Geological Survey
WAMI	Wide Area Motion Imagery
WHS	Web Hosting Service

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14. ABSTRACT

The National Guard has ongoing requirements for Incident Awareness and Assessment (IAA) capabilities to support domestic operations, and its associated training and exercises. The domestic response for Hurricanes Harvey, Irma, Nate, Maria, and the northwest wildfires in 2017 expanded use of high resolution commercial imagery and opened the aperture for use in other mission areas. This project provides an overview of current commercial high resolution unclassified satellite imagery capabilities and an analysis of how these capabilities could meet National Guard domestic response mission requirements.

15. SUBJECT TERMS: National Guard, Incident Awareness and Assessment, commercial satellite imagery, natural disasters, domestic response

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