GEOSPATIAL WORLD FORUM

TEXTRON Systems

DISASTER MANAGEMENT: Generating Imagery Intelligence Products Quickly using Machine Learning and Distribution via the Cloud

Bill Veteto
GIS Analyst
Textron Systems
1719 Dearborn Avenue
Missoula, Montana 59801
bveteto@textronsystems.com

During a natural disaster, there are often large amounts of satellite and aerial imagery that require image analysis. It is difficult for imagery specialists to analyze these large volumes of data in a timely manner, much less distribute intelligence products to emergency management agencies. Machine learning has the promise to solve much of the image analysis workload, as it avoids the need for experts to manually digitize features on each image. Textron Systems's Feature Analyst™ Extension for the ArcGIS® platform uses machine learning to classify aerial and satellite imagery. This allows image analysts to focus their energy on creating intelligence products from the classified imagery. In addition, Textron Systems' Lidar Analyst™ for ArcGIS extension automates the extraction of elevation features and provides the capability to build elevation products. Additional intelligence can be created in Textron Systems' RemoteView™ imagery analysis software. These products can be disseminated through the cloud to users via RVcloud™ software. A test case will be shown that uses recent aerial and satellite imagery of flooding from Hurricane Harvey in Houston, Texas.

Introduction

Natural disasters demand quick responses by state, local and federal agencies in order to provide timely and helpful emergency management services. Remotely sensed data can be of vital importance in assessing the scale of damage and in directing resources to the hardest hit locations. It is essential that this remotely sensed data be organized and staged in a cloud location that can be readily accessed by a wide range of users, from decision makers to GIS analysts. In addition, it is critical that users of the data are not only able to visually examine the remotely sensed images, but also to have access to a suite of tools to exploit the imagery and create image analysis products. Finally, their results need to be disseminated to other users for decisive action. Data should also be available to local systems for specialized processing and analysis. For that reason, the cloud remote sensing data management solution needs to have an intuitive and efficient data download system that allows users the capability to download selected images to their local systems. The following software products address this complex and mission-critical workflow.

GeoCatalog™ Enterprise is a scalable data management system from Textron that allows for very efficient organization of remote sensing data in the cloud. RVcloud is a web based image analysis program that provides a strong set of tools to quickly roam through imagery, create annotations, measurements and graphics for regions of interest, and publish that intelligence. The Feature Analyst and Lidar Analyst extensions for ArcGIS are two desktop software packages from Textron Systems that can quickly process large volumes of data and generate detailed analysis products that can then be pushed to users via RVcloud. RemoteView is a robust desktop image analysis platform that can do in-depth image analysis, creating both 2D and 3D analysis products that can be disseminated via RVcloud.

In the test case that follows, Digital Globe satellite imagery for Hurricane Harvey will be used to show the effectiveness of using Textron Systems cloud and desktop software. This software will be used to organize remotely sensed data, analyze that data and disseminate geospatial intelligence products to users. The Digital Globe data used in this test case is of the Houston area for the date of August 31, 2017, which was one of the peak days of flooding in the city during Hurricane Harvey.

Background: Textron Systems Cloud/Desktop Processing Options
Textron Systems offers a robust suite of cloud and desktop software that can perform a vital role in disaster management. An overview of how the various software packages combine to form a cohesive package is shown below:

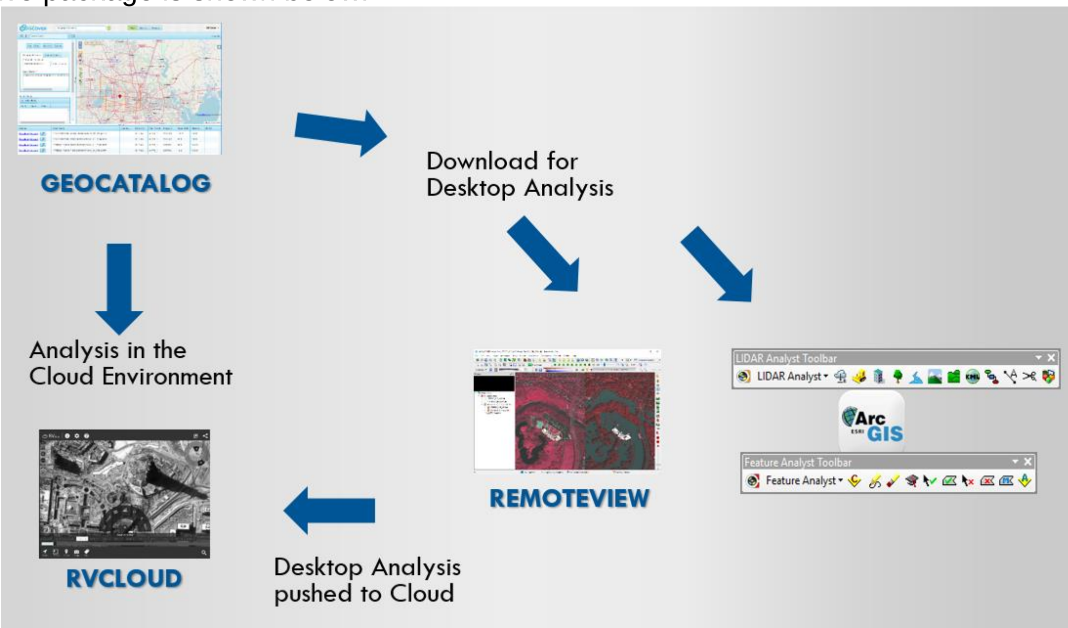


Figure 1: Workflow for data Management and analysis using Textron Systems software suite

- **GeoCatalog Enterprise:** A web based data cataloging service, cloud deployable with Amazon Web Services™. GeoCatalog Enterprise can ingest, access, manage and archive all geospatial holdings, and users can quickly locate needed imagery and data and load that data into the RVcloud browser for exploitation, or download the data to the desktop.
- **RVcloud:** Web-based thin client that can be used on mobile and desktop, HTML5 compliant, loads in imagery/data from GeoCatalog Enterprise full suite of exploitation tools, instant delivery of all high-fidelity imagery from all standard GEOINT formats, on-demand streaming of data for better performance in low-bandwidth environments.
- **Feature Analyst for ArcGIS**: Machine learning capabilities, image classification and processing, distributed processing of very large datasets.
- **Lidar Analyst for ArcGIS**: Automated processing of Lidar data to extract bare earth DEMs, buildings, tree canopy and tree points.
- **RemoteView Desktop**: Advanced imagery exploitation and analysis tools. Offers advanced terrain correction and mensuration tools, virtual mosaic capability and multi-image comparison and annotation tools.

Approach for Processing Data
The primary goal of the data processing was to use Textron Systems' suite of geospatial software to quickly generate intelligence reports in RVcloud that could be disseminated immediately and perform more advanced analysis in the desktop environment, with those intelligence reports eventually pushed to connected users via RVcloud.

The strategy for processing the data was as follows:

1) Use GeoCatalog Enterprise to organize the data
2) Use RVcloud for identifying flooded areas and making quick reports
3) Use Feature Analyst to extract flooded regions as shapefiles
4) Use Lidar Analyst to extract bare earth DEMs and then raise the elevation bare earth in areas that were flooded (as indicated in the shapefiles from Feature Analyst), then calculate the flood depth for each building
5) Generate reports in RemoteView and push those reports to RVcloud

A more detailed description of each step in the process is given below:

Organizing Data in the Cloud: A large collection of Digital Globe imagery for Houston, Texas was loaded into GeoCatalog Enterprise. The data includes imagery for Hurricane Harvey on one of the peak flood dates of August 31, 2017, and pre-flood imagery for the same area to allow for comparisons. The GeoCatalog Enterprise interface is shown below, with the entire grid of images displayed for Houston in the lower pane (image outlines in orange):

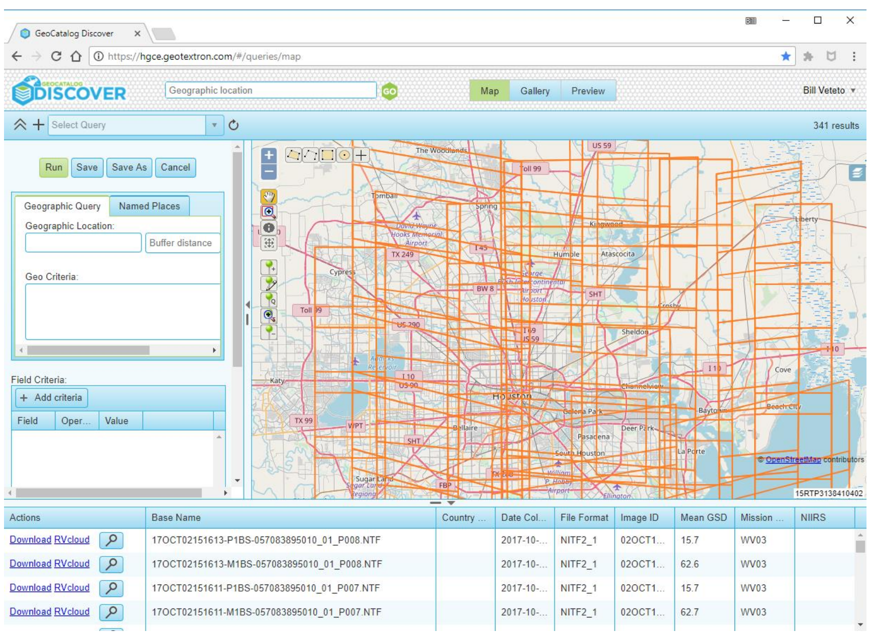
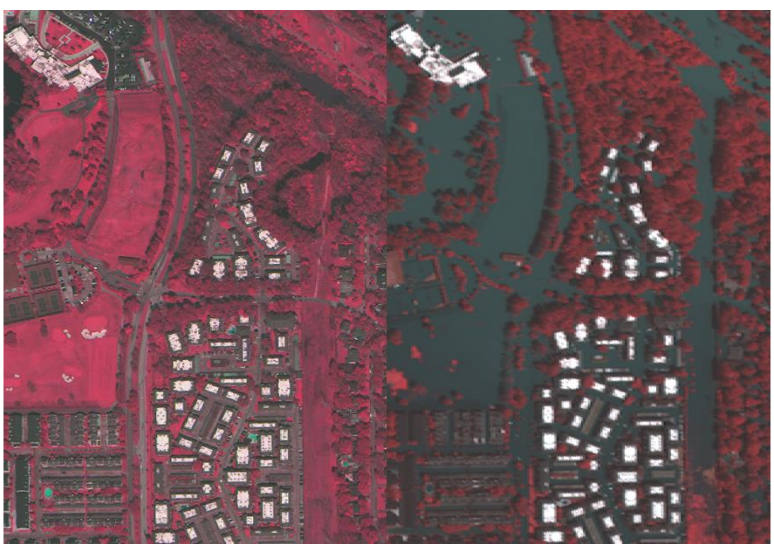


Figure 2: The GeoCatalog Enterprise Web Interface showing search results for the Houston, Texas area.

Selecting a Demonstration Area: Before and after images were selected in GeoCatalog Enterprise and loaded into RVcloud to locate areas of flooding that were suitable for use in this demonstration. A single 7.5 x 7.5 degree USGS cell in the urban Houston area was selected as a study area to demonstrate the effectiveness of Textron Systems' suite of cloud/desktop tools. The selected USGS cell, with an area of roughly 167 square kilometers, is named "Hedwig Village" and is shown below in relation to Houston, Texas:

Figure 3: Hedwig Village USGS Quad. *Image courtesy of Here via ESRI.*

This area had drainages that suffered significant flooding from Hurricane Harvey, as indicated for a small sample area shown in the comparison view below:



BEFORE **AFTER**

Figure 4: Before and after images showing flooding
Image courtesy of Digital Globe

Image Analysis in the Cloud: Imagery can be analyzed in the cloud using the RVcloud software, and intelligence products can quickly be generated and pushed out to users. RVcloud offers fast roaming through large datasets, mensuration tools and comparison tools so that before/after comparisons can be done. A sample product is shown below, with the image marked up with geographic points of interest for emergency personnel:

Figure 5: Sample image analysis product in RVcloud.
Image courtesy of Digital Globe

Desktop Analysis: Other types of analysis products can be created in the desktop environment and then pushed out to connected users via RVcloud. The Digital Globe images for August 31, 2017 were downloaded from GeoCatalog Enterprise for desktop processing using the download option in GeoCatalog Enterprise.

Desktop Processing in RemoteView: RemoteView is a desktop imagery exploitation platform widely used by the US Intelligence Community. The software offers unmatched performance to roam large image datasets, performs terrain correction on the fly to allow precise positional recording and mensuration, offers a large suite of tools to exploit imagery in both the 2D and 3D environment and can publish reports in a variety of formats.

A sample of an intelligence report from RemoteView is shown below. The image shown has been pansharpened in RemoteView and mensuration tools have been used to measure the height of the building.

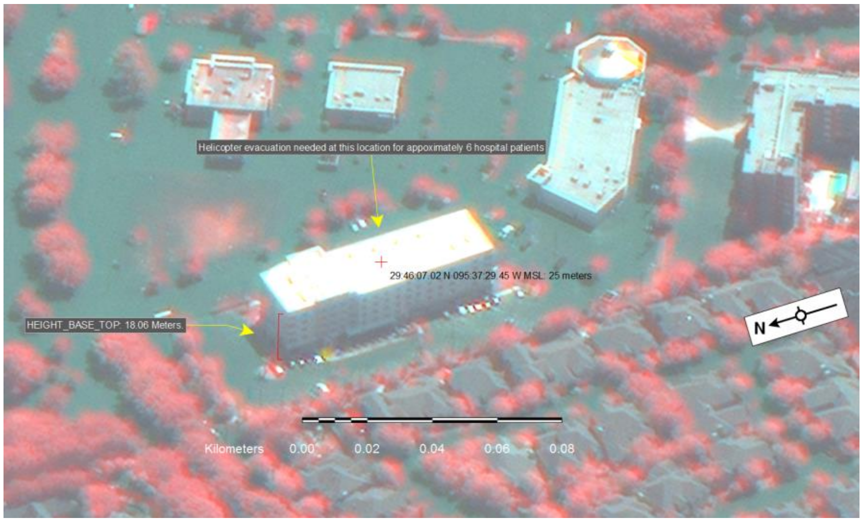


Figure 6: Sample analysis product from RemoteView desktop.

Semi-automated Water Extraction Using Feature Analyst: Feature Analyst, an extension for ArcGIS Desktop, uses machine learning to classify images. The user draws training polygons and Feature Analyst uses the training examples to learn what the target features are, then extracts those features from the given images. The extracted water features shown below are for a small area of the USGS cell and are representative of the full image:

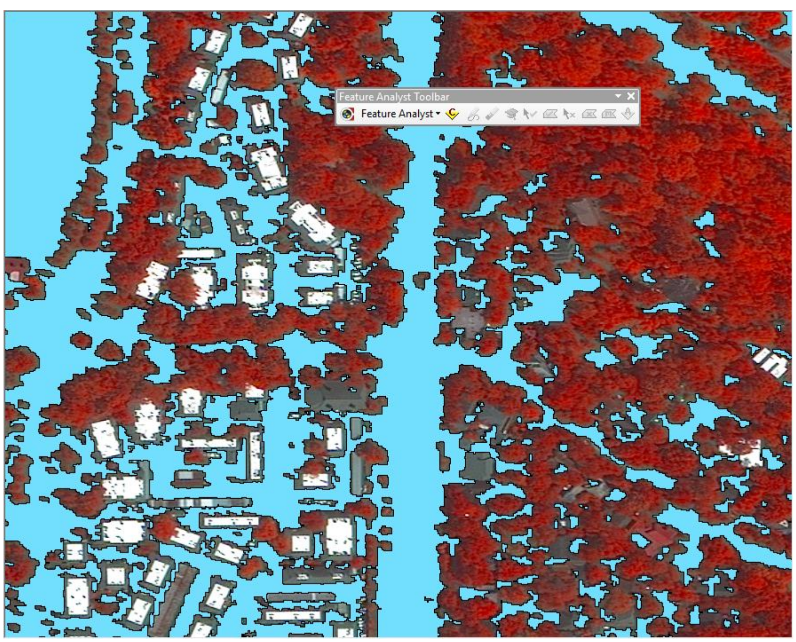


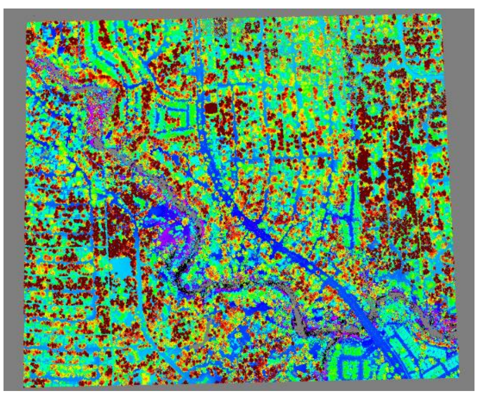
Figure 7: Feature Analyst water extraction results. *Image courtesy of Digital Globe*

	Total Area Extracted	Elapsed Time	Classification Time per square kilometer
Hedwig Village USGS Quad	167 square kilometers	11 minutes	15 square kilometers/minute

Figure 8: Table showing water extraction results.

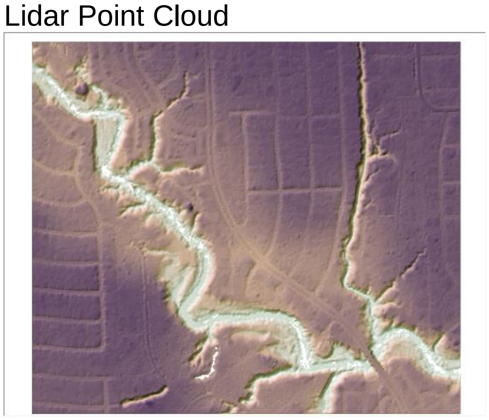
The Feature Analyst semi-automated extraction process extracted water features as a shapefile from the 167 square kilometers in the Hedwig USGS in 11 minutes, which is 15 square kilometers per minute. This is a very efficient way to extract flood coverage from images, and frees up analysts from having to manually digitize these features.

Calculating Flood Levels at Building Locations Using Lidar Analyst: Lidar Analyst, an extension to ArcGIS Desktop works directly with any type of aerial Lidar data, automatically extracting bare earth, buildings and trees. Lidar point cloud data from 2008 for Houston was downloaded from the Texas Natural Resources Information System (https://tnris.org/data-catalog/) and processed in Lidar Analyst to extract bare earth layers and to extract buildings and building points. The figure below shows the raw point cloud, as well as typical products that are extracted from the point cloud using Lidar Analyst. The products below show a small sample section of the selected USGS quad.

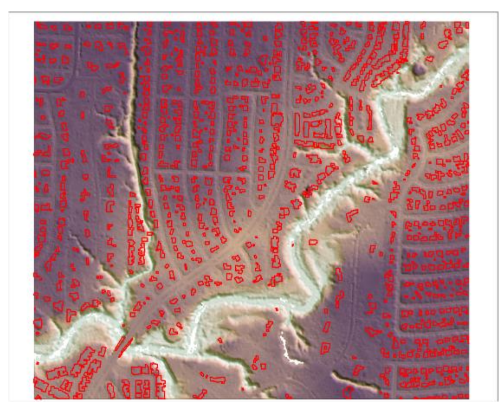


Lidar Point Cloud

Last Return DEM



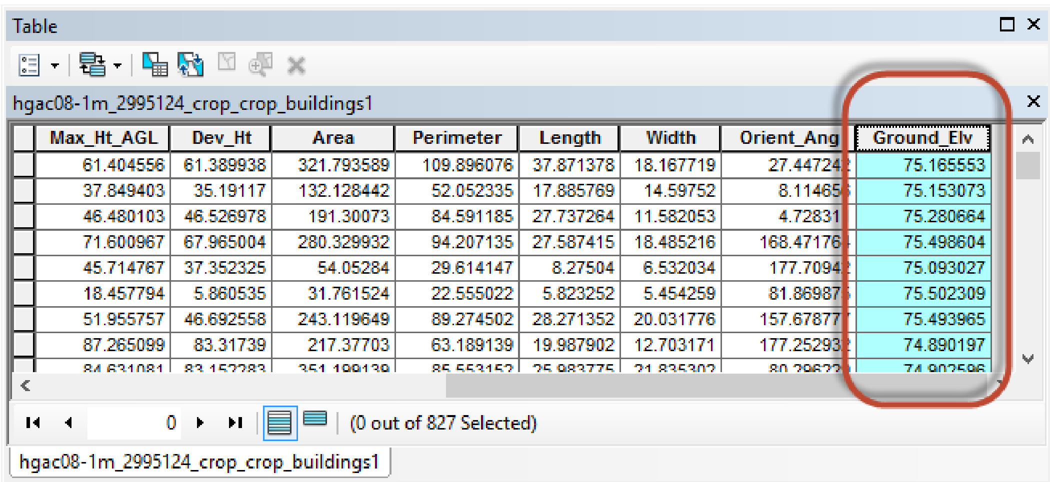
Bare Earth DEM



Automated Building Extraction Results

Figure 9: Lidar Analyst products from a typical point cloud.

Each building that is extracted from the point cloud by Lidar Analyst has many attribute fields that are automatically calculated by the software, including the ground elevation (base height) of the building:



Max_Ht_AGL	Dev_Ht	Area	Perimeter	Length	Width	Orient_Ang	Ground_Elv
61.404556	61.389938	321.793589	109.896076	37.871378	18.167719	27.44724	75.165553
37.849403	35.19117	132.128442	52.052335	17.885769	14.59752	8.11465	75.153073
46.480103	46.526978	191.30073	84.591185	27.737264	11.582053	4.72831	75.280664
71.600967	67.965004	280.329932	94.207135	27.587415	18.485216	168.47176	75.498604
45.714767	37.352325	54.05284	29.614147	8.27504	6.532034	177.7094	75.093027
18.457794	5.860535	31.761524	22.555022	5.823252	5.454259	81.86987	75.502309
51.955757	46.692558	243.119649	89.274502	28.271352	20.031776	157.67877	75.493965
87.265099	83.31739	217.37703	63.189139	19.987902	12.703171	177.25293	74.890197

Figure 10: Ground height in Lidar Analyst building attribute table.

The Lidar Analyst product has an automatic extraction process is very efficient in processing large areas. Statistics for the extracted features in the Hedwig USGS section are shown below:

	Square Kilometers	Bare Earth Extraction (minutes)	Number of Buildings Extracted	Buildings Extracted per Minute
Hedwig USGS Quad	167	504	48844	96

Figure 11: Statistics for Lidar Analyst extractions.

The flooding extent shapefile that was extracted earlier from the satellite imagery for the USGS quad was brought into Lidar Analyst, and using this file a re-interpolation was done on the bare earth DEM to add the flood height to the bare earth surface to create a new “flood level DEM.” For illustration purposes, the screenshot below shows the flood water in pink in a 3D view, with affected buildings surrounded by the water. Note that the buildings are shown on the bare earth surface:

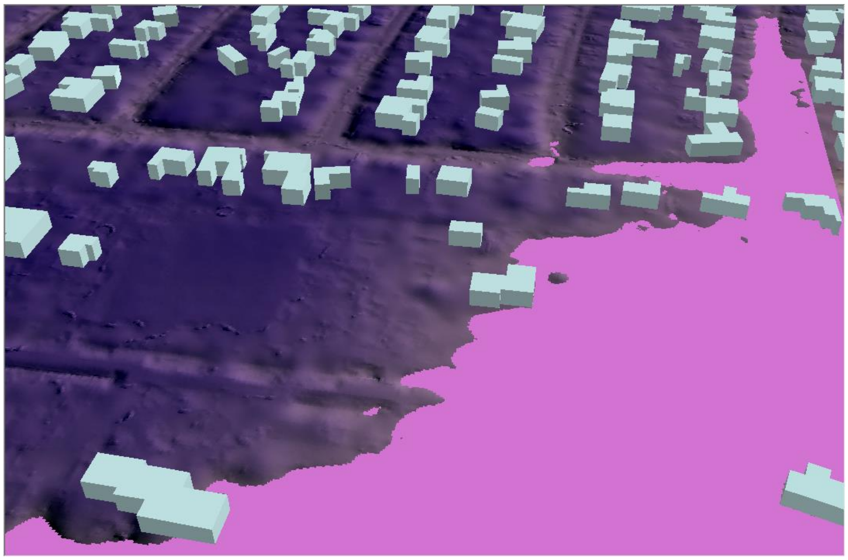


Figure 12: Buildings in 3D view on bare earth DEM with flood layer overlapping some homes.

A flood calculation was done for each building by subtracting the base elevation level for each building from the Lidar Analyst derived flood inundation level at that same location. The drawing below illustrates this calculation:

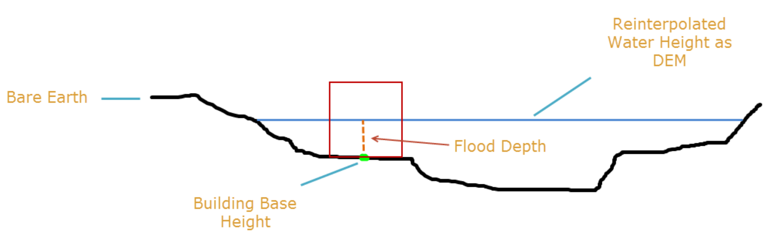


Figure 13: Calculation for flood depth.

As a result of this calculation, each building affected in the flooded region of the Hedwig USGS quad was assigned a value that shows the depth to which the building was flooded. The building polygons were converted to points, and symbology was applied to show the flood depth levels. Results for one of the sections in the Hedwig Village tile are shown below:

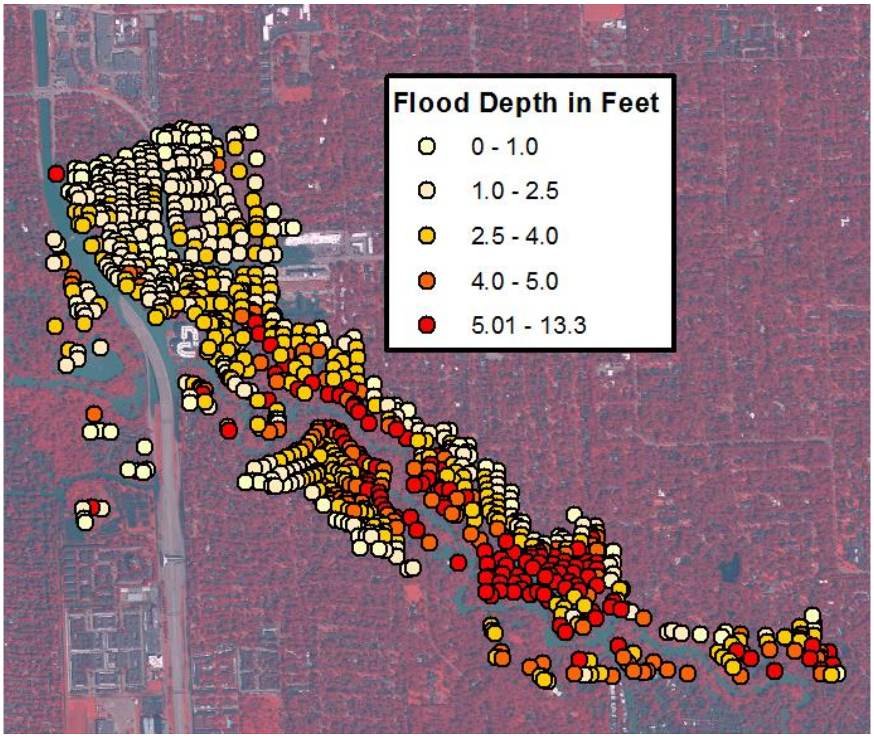


Figure 14: Building points showing symbology for flood depth calculation layer.
Imagery courtesy of Digital Globe.

Next, map products showing building points affected by the flooding were pushed out to RVcloud:

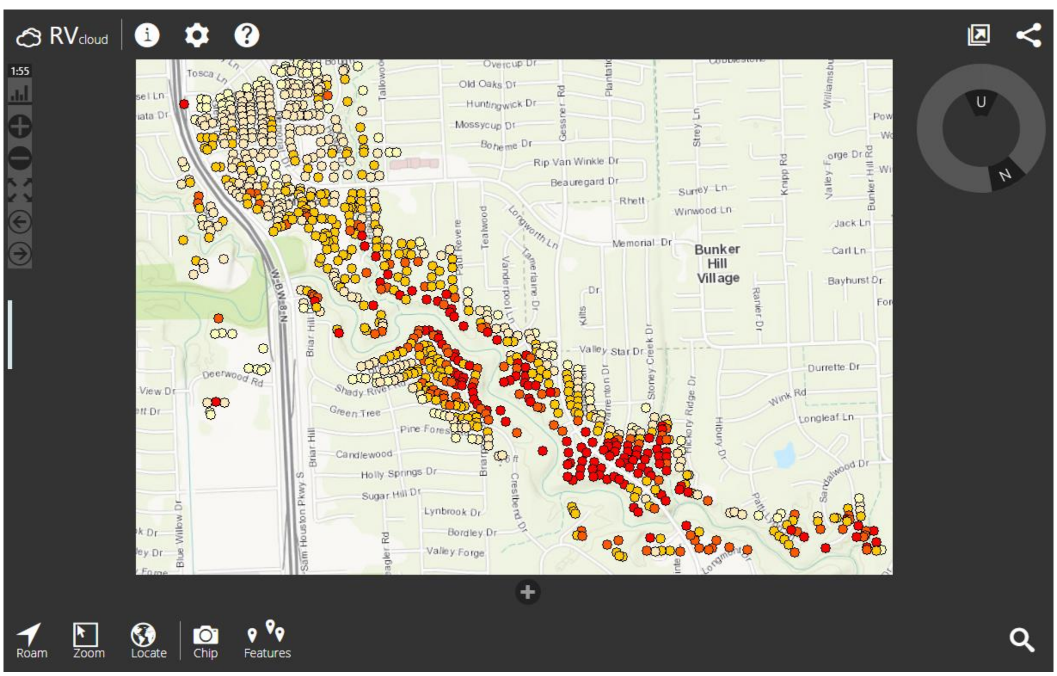


Figure 15: Map product in RVcloud.

Conclusion

Textron Systems' geospatial suite of tools, utilizing both cloud and desktop environments, help analysts process large collections of satellite imagery and other ancillary data and speed the distribution of intelligence products to analysts and decision makers. In the test case showing the use of Textron Systems' software suite for Hurricane Harvey, the capabilities demonstrated show that the software brings a robust toolset to bear on the problem, giving managers and GIS analysts solutions to find imagery, exploit that imagery and quickly produce analysis products that can show the impacts of the storm and direct resources to where they will be most helpful.

- Paper Reference No.: PN-140
- Title of the paper: Disaster Management: Generating Imagery Intelligence Products Quickly using Machine Learning and Distribution via the Cloud
- Name of the Presenter: William Veteto
- Author Affiliation: Textron Systems
- Mailing Address: 1719 Dearborn Avenue, Missoula MT 59801
- Email Address: bveteto@textronsystems.com
- Telephone number: 406-829-1384
- Fax number: 406-829-3539
- Author's Photograph:

- Biography:

William Veteto is based in Missoula Montana, and has worked as a GIS Analyst and Product Support Lead for Textron Systems Geospatial Solutions for 12 years. He received a BA in Geography from the University of Memphis and a M.S. in GIS/Cartography from the University of Montana.