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Military Engineering Program: Mobility in Complex Urban Environments

Urban Terrain Data Availability and Gaps

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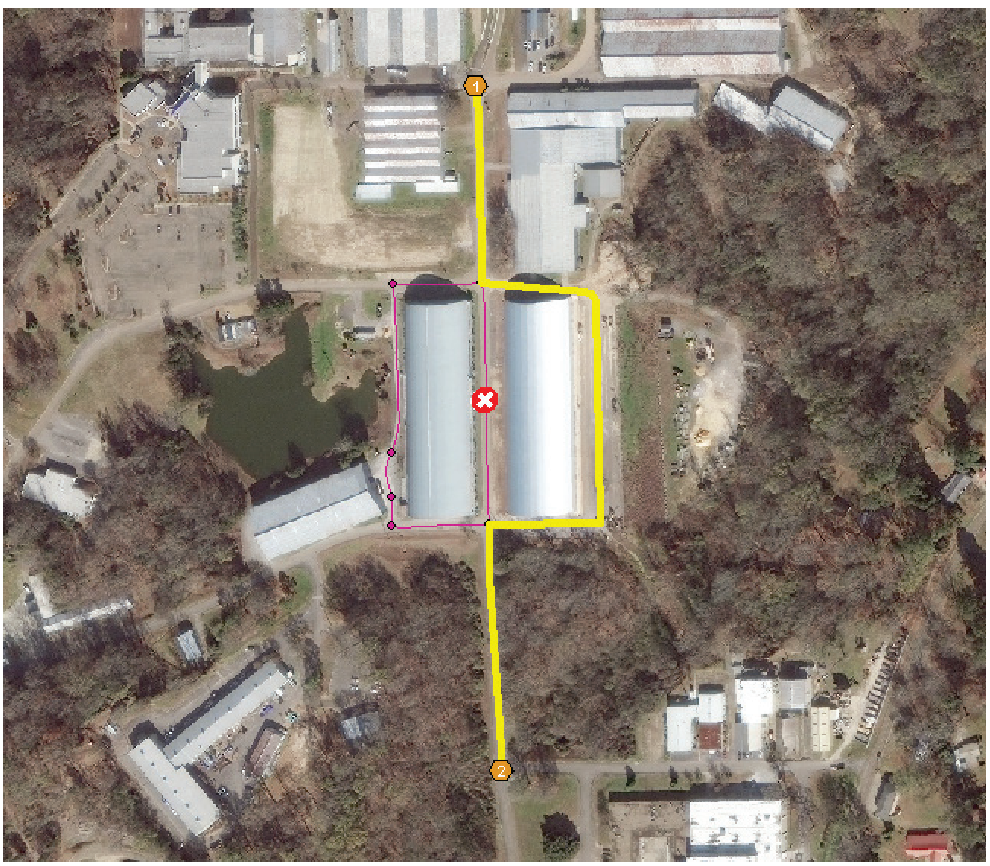

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Abstract

Real-time urban mobility modeling presents a unique challenge in the area of terrain representation. The terrain must be sufficiently detailed to depict real limitations on vehicle movement, but it must also be transmitted, stored, and processed efficiently enough to allow rapid mobility estimates in a moving vehicle. Moreover, urban environments have different mobility limitations than off-road environments. The primary limitation to mobility in urban areas is expected to be geometry, which includes roadway width, intersection configurations, and overhead restrictions. Additional limits may be caused by static and dynamic obstacles and by bridge capacity limits, which are commonly expressed in terms of Military Load Classification (MLC). Local traffic control measures (e.g., stop signs, traffic lights) may also need to be considered, depending on the desired operation procedures. The goals of this report are to summarize the available baseline geospatial datasets for use in mobility analysis of urban areas and to expose gaps in data availability.

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Preface

This study was conducted for the Engineer Research and Development Center - Geotechnical and Structures Laboratory (ERDC-GSL) under the Military Engineering Program FWIC 6B6F05, “Mobility in Complex Urban Environments (MCUE).” The technical monitor was Mr. Josh Fairley ERDC-GSL. Dr. Robert Wallace, Engineered Resilient Systems, U.S. Army Engineer Research and Development Center, Information Technology Laboratory (ERDC-ITL) was the Technical Director.

The work was performed by the Computer Aided Design/Building Information Modeling (CAD/BIM) Technology Center of the Software Engineering and Informatics Division (SEID), ERDC-ITL and the Mobility Systems Branch of the Engineering Systems and Materials Division (ESMD), ERDC-GSL. At the time of publication, Mr. Edward L. Huell Jr was the Chief of the CAD/BIM Technology Center, Mr. Ken C. Pathak was the Chief of the SEID, Ms. Patti S. Duett was the Deputy Director of ITL, and Dr. David A. Horner was the Director of ITL.

Mr. Greg Green (GSL) was the Real-Time Mobility Pillar Lead, Mr. Josh Fairley (GSL) was the MCUE Program Manager, Ms. Stephanie Price was the MCUE Deputy Program Manager, Mr. Phillip J. “Jeff” Durst (GSL) was Branch Chief of the Mobility Systems Branch (GMM), Dr. Timothy W. Rushing (GSL) was Acting Chief of the ESMD, Mr. Nicholas R. Boone (GSL) was the Military Engineering Technical Director, Mr. Charles W. Ertle was the Deputy Director of GSL, and Mr. Bartley P. Durst was the Director of GSL.

COL Ivan P. Beckman was the Commander of ERDC, and Dr. David W. Pittman was the Executive Director of ERDC.

Acronyms and Abbreviations

AGC	Army Geospatial Center
DEM	Digital Elevation Models
DoD	Department of Defense
DTED	Digital Terrain Elevation Data
ERDC	U.S. Army Engineer Research and Development Center
ERS	Engineering Route Study
ESMD	Engineering Systems and Materials Division
EV-WHS	EnhancedView-Web Hosting Services
Ft	foot/feet
GEOINT	Geospatial Intelligence
GSL	Geotechnical and Structures Laboratory
ITL	Information Technology Laboratory
k	Kilometer
KIAS	Knots-Indicated Air Speed
LiDAR	Light Detection and Ranging
m	Meters
METM	Map Edit Tasking Manager
MCUE	Mobility in Complex Urban Environments
MLC	Military Load Classification

MrSID	Multi-resolution Seamless Image Database
NATO	North Atlantic Treaty Organization
NGA	National Geospatial-Intelligence Agency
NOME	NSG Open Mapping Enclave
NRMM	NATO Reference Mobility Model
NSG	National System for Geospatial Intelligence
OSQA	Open Source Question and Answer
POIs	Points of Interest
RCI	Rating Cone Index
SEID	Software Engineering and Informatics Division
SRTM	Shuttle Radar Topography Mission
TIFF	Tagged Image File Format
TREx	TanDEM-X High Resolution Data Exchange
UAS	Unmanned aerial system
UTP	Urban Tactical Planner
VehDyn	Vehicle Dynamics Module
2d	Two dimensional
3d	Three dimensional

1 Introduction

1.1 Background

Urban environments pose many new operational and tactical challenges for the U.S. Army and Joint Forces. One of the most daunting of these is ground vehicle maneuver in urban environments (FM 3-06). While many improvements have been made in protecting ground vehicles in the last decade, these improvements come with a cost, specifically limited situational awareness due to reduced visibility and limited maneuverability in tight spaces because of larger vehicle size. Both of these constraints seriously reduce the mobility of ground vehicles in urban environments. The Mobility in Complex Urban Environments (MCUE) research program addresses these shortcomings by using emerging technologies in sensors and data processing to provide better situational awareness in near real-time to ground vehicle operators maneuvering in dynamic urban terrain.

The primary product of MCUE will be a demonstrated prototype system that provides early warning for urban hazards, threats, and obstacles. The warning system will use a variety of sensors mounted on an unmanned scout vehicle to detect pedestrians, buried threats, anomalous traffic activity, as well as narrow and blocked roadways.

A tiered information collection approach will be used to characterize the urban operating environment. In Tier 1, readily available information from remote sensing and geographic information systems will be used to assess the area and plan a route. In Tier 2, an unmanned aerial system (UAS) will be used to collect higher resolution and more recent images of the selected route and alternate routes. Finally in Tier 3, a UAS will be deployed a short distance ahead of a convoy to detect any changes to the route. Data collected by the UAS will be communicated back to the ground vehicle to warn the convoy leader of obstacles and threats along the route.

Real-time urban mobility modeling presents a unique challenge in the area of terrain representation. The terrain must be sufficiently detailed to depict real limitations on vehicle movement, but it must also be transmitted, stored, and processed efficiently enough to allow rapid mobility estimates in a moving vehicle.

Moreover, urban environments have different mobility limitations than off-road environments. The primary limitation to mobility in urban areas is expected to be geometry, which includes roadway width, intersection configurations, and overhead restrictions. Additional limits may be caused by static and dynamic obstacles (e.g., potholes, ditches, rubble, pedestrians, and traffic) and by bridge capacity limits, which are commonly expressed in terms of Military Load Classification (MLC). Local traffic control measures (e.g., stop signs, traffic lights) may also need to be considered, depending on the desired operation procedures.

Existing mobility models, such as the North Atlantic Treaty Organization (NATO) Reference Mobility Model (NRMM) and the vehicle dynamics module VehDyn, are able to account for many of these factors. However, in past studies, the terrain data for road analysis within such models has not been readily available.

1.2 Objectives

The objectives of this report are to summarize the available baseline geospatial datasets for use in mobility analysis of urban areas and to expose gaps in data availability.

1.3 Approach

The following three types of data needs were examined: (1) reference imagery to provide an initial overview of the area for the MCUE image classification system, (2) road network data to use in vehicle routing and mobility modeling, and (3) elevation data to compute surface slopes.

Not all datasets were given equal consideration for this report. First preference was given to U.S. Army official data sources. Furthermore, data sources that provide either global coverage or large regions were considered. For instance, if a road network is desired for a town in the United States, the maps maintained by the municipal, county, or state geodatabase may contain useful road data. However, such data is likely to be formatted and attributed differently than data from the geodatabase of the next city, county, or state. Considerable effort may be needed to import data from each of these localized geodatabase. Even if the data can be successfully imported into a common system, there is no guarantee that the data will be consistent from one source to the other. Therefore, priority was given to global or large regional data sources.

Other items of consideration include data attribute completeness and data timeliness. Sample datasets were obtained for each data source to verify whether data attributes are consistently available across different world urban areas.

1.4 Scope

The scope includes exploring what baseline geospatial datasets are available for use in mobility analysis for urban areas. This exploration will expose gaps in data availability, which will lead to request to the Dynamic Sensing Pillar for potential solutions for these gaps.

2 Imagery

2.1 Background

Sensing and image processing are key components of the MCUE program. Current research is developing techniques to automatically identify roads, obstacles, threats, and other urban features from high resolution imagery. Analyst-in-the-loop classification schemes require manpower from skilled analysts that may not be readily available for Army missions (FM 3-06.11). Although the emphasis began with imagery collected by UAS flying ahead of a convoy, similar techniques may be useful for processing images from other data sources. Additionally, imagery may be used directly to provide a background for maps so that users have visual awareness of the area of interest.

2.2 Desired data

The usefulness of imagery data to identify features depends on the resolution of the imagery, which is expressed in several ways.

Spatial resolution of an image is the level of fine detail that can be discerned from the image. A common comparison metric for spatial resolution is pixel size; images with smaller pixels provide better resolution. For urban environments, high spatial resolution is key to discerning small features of the complex landscape (Liang et al. 2012).

Spectral resolution refers to the wavelength intervals recorded in an image. Bands of different wavelengths can be used by image classifiers to discern features. In addition to specific documentation of bands and their wavelength ranges, images are often broadly described as panchromatic (with only one band across a broad spectrum), multi-spectral (with a small number of bands, usually 3–10), and hyperspectral (with hundreds of narrow bands) (Liang et al. 2012).

Radiometric resolution refers to how finely the shades of brightness response on a band are recorded. This is commonly expressed in terms of how many bits are used to store the brightness. The higher numbers of bits, the better resolution (Liang et al. 2012).

Temporal resolution of a sensor system refers to how often new imagery is available from the system. For MCUE, up to date imagery is preferred, but shortcomings in this area will be mitigated with new imagery obtained by UAS. Additionally, it is helpful to consider seasonal effects on imagery. Depending on the area of interest, clouds, snow, and vegetation can have significant impacts on image analysis throughout the year (Liang et al. 2012).

All sensor systems have tradeoffs in these types of resolution. For instance, it is easier for a system to have shorter revisit times (better temporal resolution) if it covers a broader area at one time; however, that could mean that it will capture coarser pixels (worse spatial resolution).

2.3 DigitalGlobe (WorldView) imagery

DigitalGlobe is a commercial vendor of satellite imagery. The National Geospatial-Intelligence Agency (NGA) has a contract in place with DigitalGlobe to provide Department of Defense users with access to their images from WorldView satellites via the EnhancedView Web Hosting Services (EV-WHS, https://evwhs.digitalglobe.com).

Full details about WorldView sensors are available from DigitalGlobe (https://www.digitalglobe.com/resources/satellite-information). For reference, selected specifications are listed in Table 1.

Table 1. Selected specifications of currently active DigitalGlobe satellites.

	WorldView- 1	GeoEye-1	WorldView- 2	WorldView- 3	WorldView- 4
Bands	1 Panchromatic	Panchromatic + 4 Multi-spectral	Panchromatic + 8 Multi-spectral	Panchromatic + 8 Multi-spectral	Panchromatic + 4 Multi-spectral
Panchromatic Pixel Size (m)	0.50	0.41	0.46	0.31	0.31
Multi-spectral Pixel Size (m)	N/A	1.64	1.85	1.24	1.24
Spatial Accuracy (m CE90)	6.5	3	6.5	3.5	4
Revisit time (days)	1.7	< 3	1.1	1.0	1.0
Bits per pixel	11	11	11	11	11

2.3.1 Washington D.C. sample data

Sample images of Washington, D.C, were obtained to verify expected image quality (Figure 1). Pan-sharpened multi-spectral images from both WorldView-2 (approximately 0.5 meters (m) resolution) and WorldView-3 (approximately 0.3 m resolution) provide adequate resolution to identify and measure large objects such as buildings and streets (Figure 2).

Figure 1. Sample WorldView3 imagery of a city block in Washington, D.C.

Figure 2. Example of measuring road dimensions (shown in meters).

2.3.2 Data comparison

Although DigitalGlobe satellites fly over most of the world's surface at least once per day, not all of that data is collected and made available. Table 2 provides a comparison of the number of images available for various world cities. These numbers were determined using the "Advanced Search" feature of the EnhancedView-Web Hosting Services EV-WHS. A 12 kilometer (km) by 12 km area of interest was drawn near the approximate city center, and images were filtered to include only imagery from 1 January 2016 to the date of the comparison (9 November 2018). To further understand the available data, filters were also added for images that were pan-sharpened and images that had less than 15% cloud cover.

Table 2 shows that not all world areas have equal amounts of usable imagery. Areas where the imagery is not commonly requested (e.g., Vicksburg, MS and Muscatatuck, IN) have fewer images overall. Also, some areas are more likely to have cloud cover (e.g., San Jose, Costa Rica).

Table 2. Comparison of the number of images available for various world cities.

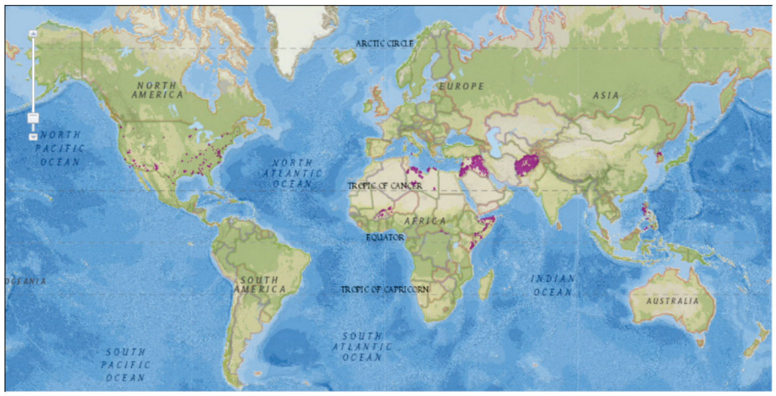
City	Total Images	Pan-sharpened		Pan-sharpened, < 15% Clouds	
Washington, D.C	195	136	70%	108	55%
Lima, Peru	168	111	66%	69	41%
San Jose, Costa Rica	158	147	93%	63	40%
Aleppo, Syria	128	99	77%	88	69%
Moscow, Russia	71	62	87%	40	56%
Paris, France	44	32	73%	27	61%
Muscatatuck, IN	25	21	84%	15	60%
Vicksburg, MS	8	4	50%	4	50%

2.4 Buckeye

Buckeye is an Army Geospatial Center (AGC) mission intended to provide high resolution imagery and elevation data. Additional information about the elevation data is discussed in section 4.6.

Multi-resolution Seamless Image Database (MrSID) is a powerful wavelet-based image compression algorithm with multiple compression ratios. MrSID raster images have been prepared for certain areas within the following regions: Afghanistan, Burkina Faso, Central African Republic, Democratic Republic of Congo, Iraq, Jordan, Kenya, Lebanon, the Philippines, and the United States of America. These files are two dimensional (2D) raster images of the terrain data that were captured during Light Detection and Ranging (LiDAR) readings (Figure 3).

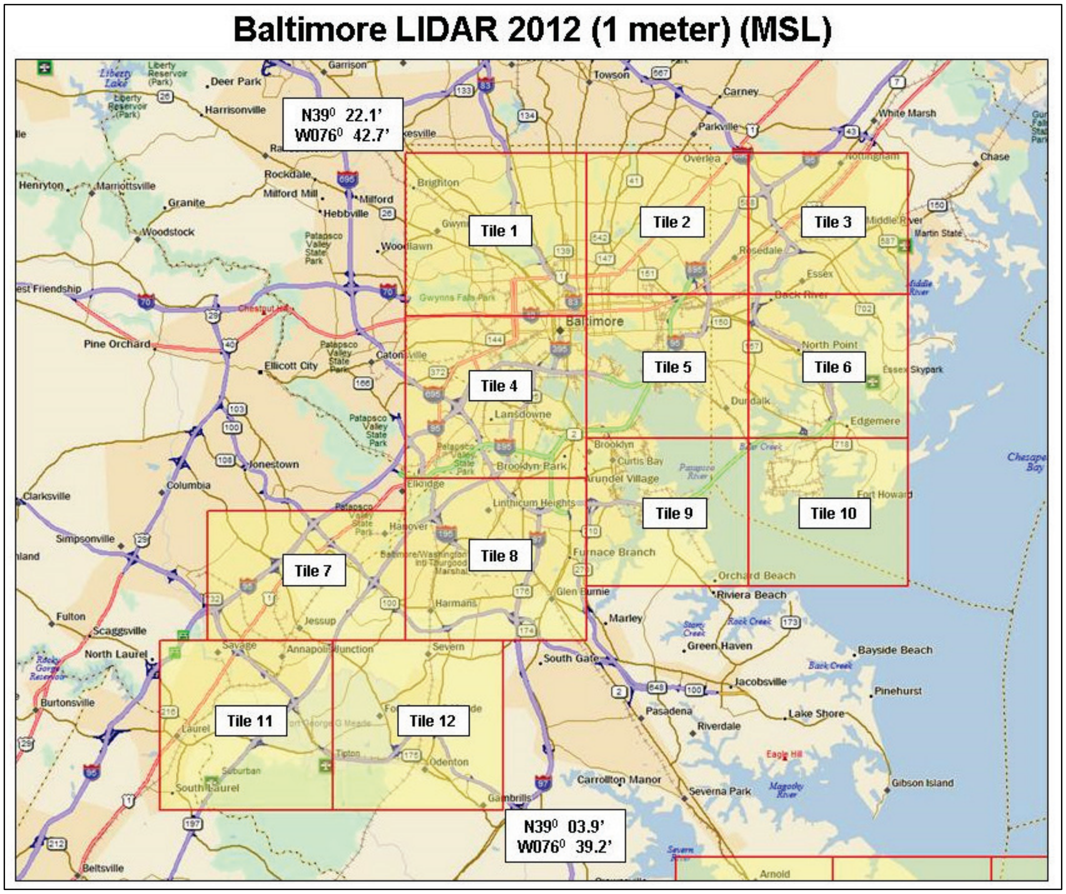
Figure 3. Buckeye coverage.



2.4.1 Baltimore sample data

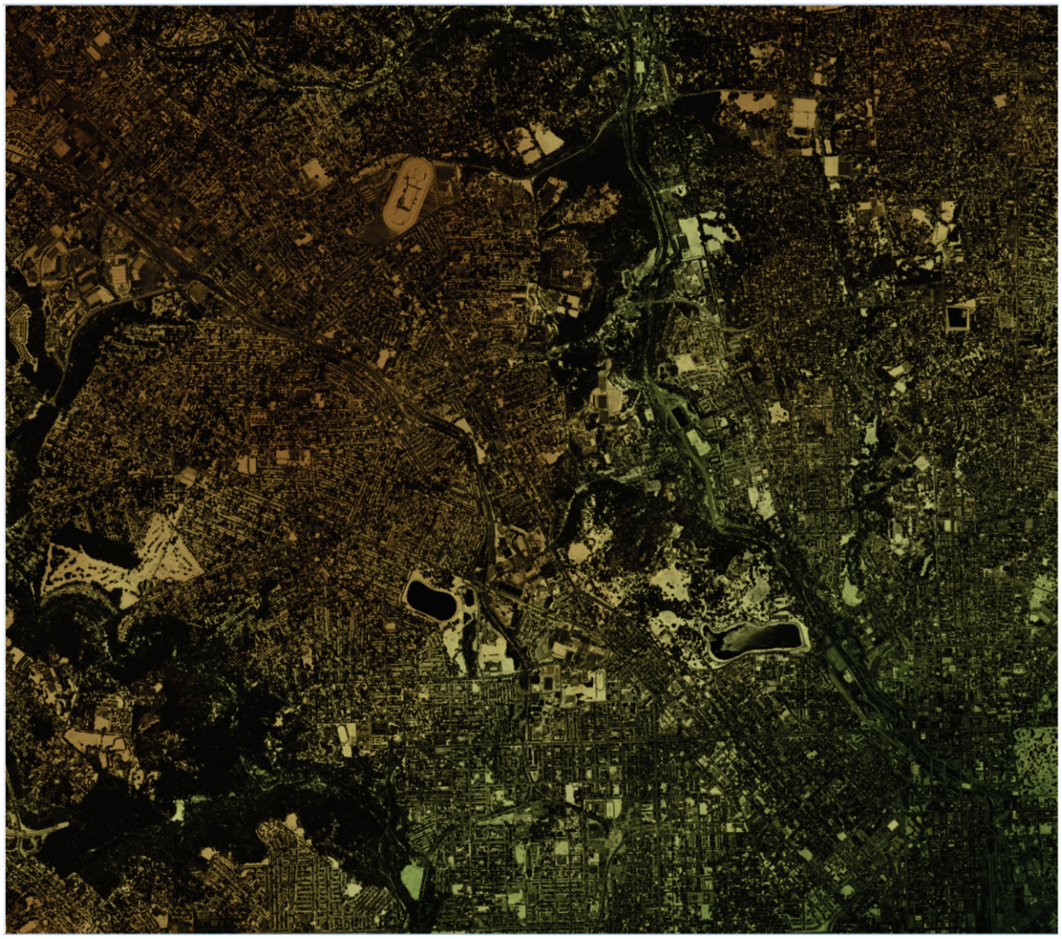
The first step in analyzing the Baltimore Buckeye data is to open the folder for USA (https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/US), then open the folder for Maryland, and finally open the Baltimore folder. Inside of the Baltimore folder there are many different folders. First, open the .jpg file that will show the Lidar Index for Baltimore. This file will show which tile the location to be analyzed is located in. Once the tile that encompasses the area to be analyzed is found, then open the file to that tile. For this effort, analyzing the files and extractable data located in the Tile 1 folder will be shown (Figure 4).

Figure 4. Baltimore LiDAR index.



Tile 1 folder includes two 2D tagged image file format (tiff) files that consist of imagery, which can be draped over the digital elevation models (DEMs) to add imagery (Figure 5).

Figure 5. 2D tiff imagery.



.tif.xml

These .tif.xml files contain metadata about the GeoTiff files. Each GeoTiff file has a corresponding .tif.xml file stored inside the folder. The following data is included on the Baltimore Tile 1 .tif.xmls:

- Resolution: 1 m
- Type of Surface: reflective surface
- Type of Model: DEM
- Begin Date: 2012/09/10
- End Date: 2012/09/13
- Latitude and Longitude Data
  - West boundary condition: -93.669876
  - East boundary condition: -93.252115
  - North boundary condition: 44.937917
  - South boundary condition: 44.677752
- Other Boundary Conditions (not sure of units):

  - Left boundary condition: 447145.000000
  - Right boundary condition: 480019.000000
  - Bottom boundary condition: 4947370.000000
  - Top boundary condition: 4976085.000000
- Average ground sample distance: 1 m
- Sources of Data
- Horizontal Accuracy: 0.5 m
- Vertical Accuracy: 0.005 m
- Root Mean Square Error (RMSE): 0.07 m
- Type of Scanner: Leica Systems ALS70
- Data acquisition height: 7500 feet (AGL)
- Scanner field of view: 36.9 Hz
- Pulse Repetition Rate: 239 kHz
- Aircraft Speed: 150 KIAS
- Swath width: 5460 ft
- Nominal ground sample distance: 3.0 ft
- Number of returns per pulse: 2
- Distance between flight lines: 3822 ft
- Raster image coordinates
- Projected coordinate system: WGS 1984 UTM Zone 15N
- Datum: 1988 North American Vertical Datum
- Projection: Transverse Mercator

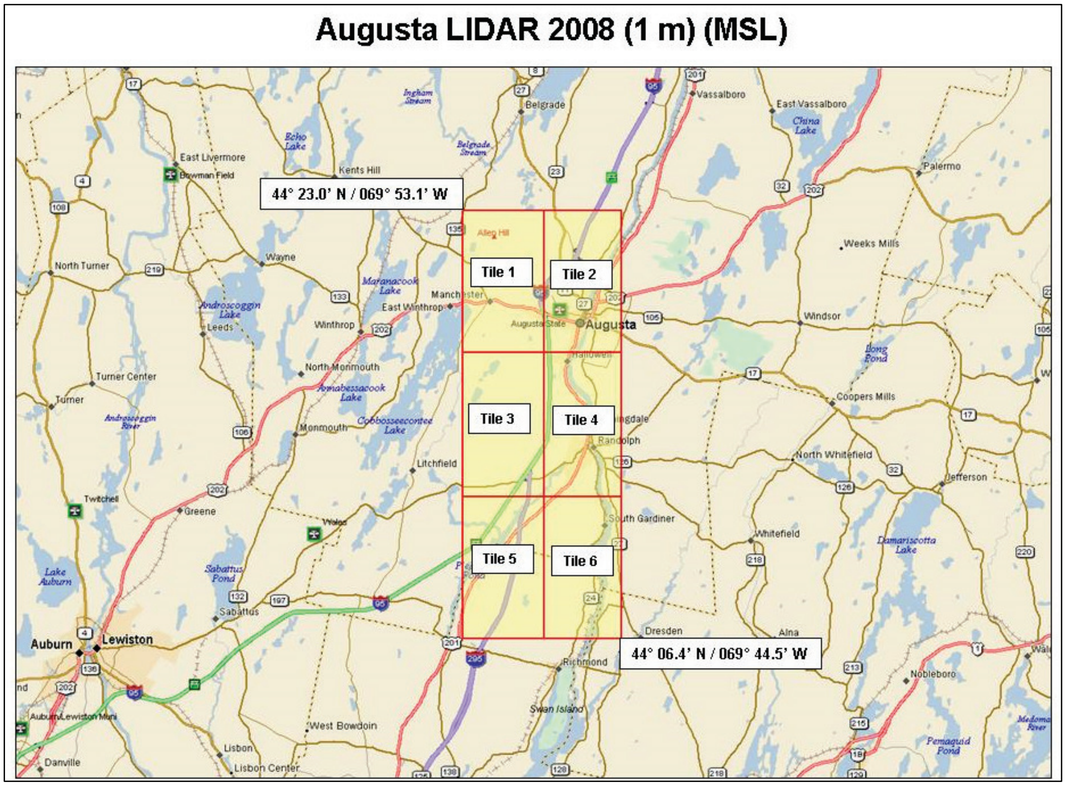
MrSID files

There are no MrSID files available for Baltimore, MD.

2.4.2 Maine sample data

The first step to analyzing the Maine Buckeye study is to open the folder for USA (https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/US), and then open the folder for Maine. Inside of the Maine folder there are three different study areas. The three concentration areas of the Maine Buckeye study are Augusta, Callahan Mine, and the Maine border. First, the Augusta ME folder was analyzed. Inside, the Augusta folder contains many different folders. First, open the .jpg file that shows the Lidar Index for Augusta. This file will show which tile for the location to be analyzed is located in. Then once the tile that encompasses the area to be analyzed is opened, then open the file to that tile. For the purpose of this study, analyzing the files and extractable data located in the Tile 1 folder will be completed (Figure 6).

Figure 6. Augusta tile index.



Tile 1 folder includes 2D tiff files that consist of imagery, which can be draped over the DEMs to add imagery (Figure 7).

Figure 7. Augusta 2D TIFF imagery.

Augusta .tif.xmls

These .tif.xml files contain metadata about the GeoTiff files. For Augusta, only one GeoTiff file has a corresponding .tif.xml file stored inside the folder. The following data is included on the Augusta Tile 1 .tif.xml:

- Resolution: 1 m
- Publish Date: 04/2008
- Type of Surface: reflective surface
- Type of Model: DEM
- Begin Date: 2012/09/10
- End Date: 2012/09/13
- Latitude and Longitude Data
  - West boundary condition: -69.886550

  - East boundary condition: -69.738059
  - North boundary condition: 44.390376
  - South boundary condition: 44.105779
- Other Boundary Conditions (not sure of units):
  - Left boundary condition: 429388.000000
  - Right boundary condition: 440933.000000
  - Bottom boundary condition: 4884000.000000
  - Top boundary condition: 4915500.000000
- Average ground sample distance: 1 m
- Sources of Data
- Horizontal Accuracy: 0.5 m
- Vertical Accuracy: -0.0014 m
- Root Mean Square Error (RMSE): 0.0812 m
- Type of Scanner: Leica Systems ALS50 II
- Data acquisition height: 4000 ft (AGL)
- Scanner field of view: 40 degrees
- Scan frequency: 36.78 Hz
- Pulse Repetition Rate: 80 kHz
- Aircraft Speed: 130 KIAS
- Swath width: 888 m
- Nominal ground sample distance: 3.0 ft
- Number of returns per pulse: 2
- Distance between flight lines: 622 m
- Raster image coordinates
- Projected coordinate system: WGS 1984 UTM Zone 19N
- Datum: 1988 North American Vertical Datum
- Projection: Transverse Mercator

MrSID files

MrSID files are 2D raster images of the terrain data that was captured during Lidar readings. The first step is to open the webpage to view MrSID files for the U.S. https://cac.agc.army.mil/Products/filelib.cfm?d=%2Fortho%5Fimages%2FUSA. Inside the Maine subfolder there is only one area that contains MrSID files and that area is Callahan Mine. The Callahan Mine folder includes many zipped files, a metadata.xml file, and a jpg image that serves as the tile index. The tile index breaks down the Callahan Mine into smaller areas (Figure 8).

Figure 8. Callahan Mine MrSID tile index.

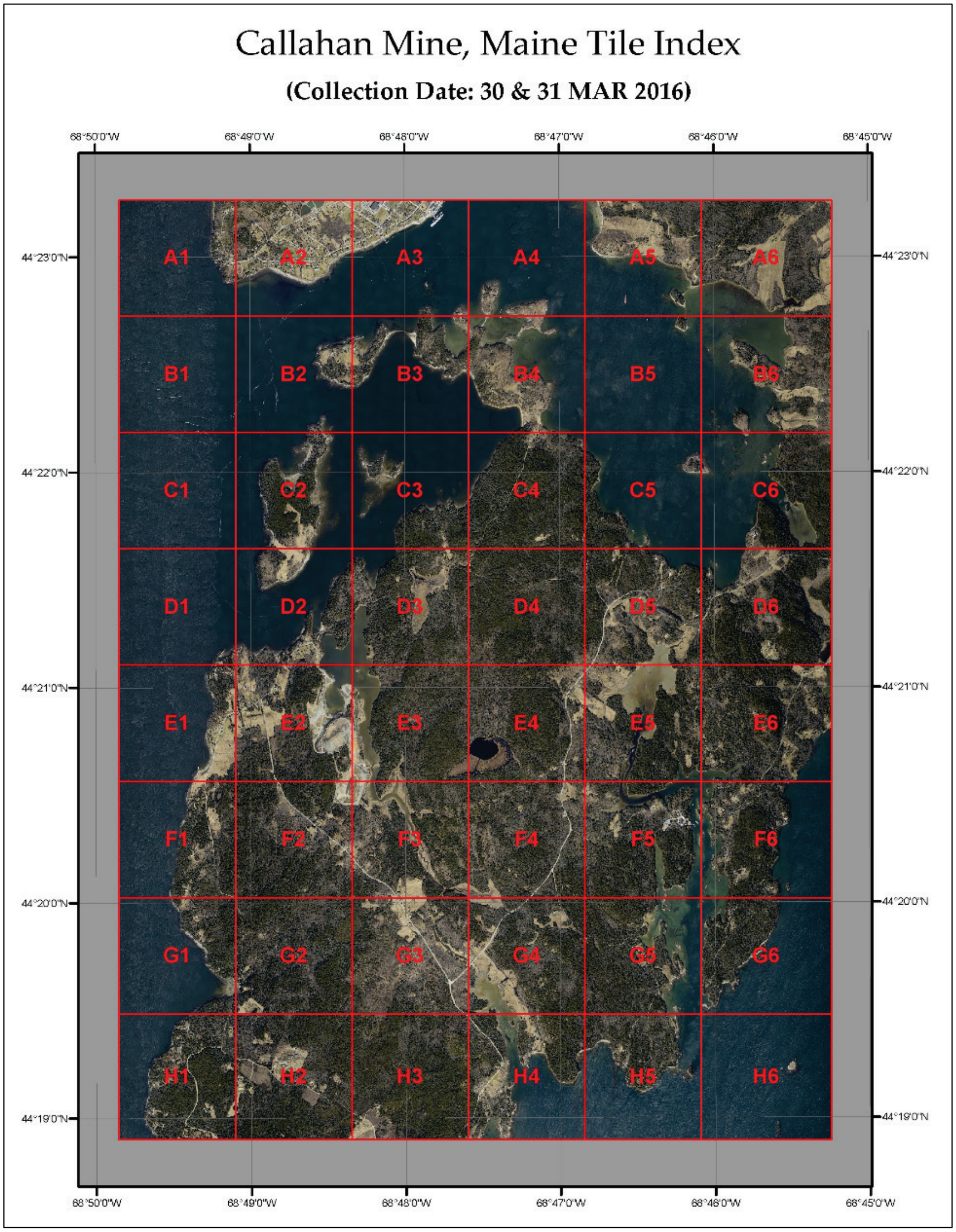


Figure 8 shows that these zones are much smaller than the other Lidar Index files, meaning that the MrSID imagery should have much more detail than the tiff imagery. For this review, the E2 zip file will be examined. E2 was chosen because of the abundance of different features in this tile.

The E2 zip file contains the MrSID file for the area E2. This file shows ortho-rectified image mosaics of the E2 tile in Callahan Mine. This color imagery can be draped over Lidar points to create a visually and geographically accurate surface model (Figure 9).

Figure 9. Callahan Mine MrSID imagery.

2.4.3 South Korea sample data

The first step to analyzing the South Korea Buckeye study is to open the folder for the Korean Peninsula https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/Korea, and then open the folder for South Korea Vricon Rodriguez Range. Inside of the South Korea Vricon Rodriguez Range folder there are two subfolders. The two subfolders are South Korea Vricon DSM WGS84 Rodriguez Range and South Korea Vricon True Ortho Rodriguez Range.

Inside of the South Korea Vricon DSM WGS84 Rodriguez Range, there are four GeoTiff files that when opened simultaneously in the QTReader show the entire digital surface model of the Rodriguez Range.

Inside of the South Korea Vricon True Ortho Rodriguez Range folder there are four .tex.tif files that correspond with each of the four GeoTiff files. This tex.tif files include high quality color imagery that can be draped over the GeoTiff digital surface model (Figure 10). Once the imagery has been draped over the digital surface model, the new digital surface model will show terrain along with imagery. Also included in this folder is a metadata.json file that includes some data about the tex.tif files, but this file must be opened in ArcCatalog to view all of the metadata.

Figure 10. Rodriguez Range (South Korea) tex.tif imagery.

2.5 Conclusion

The WorldView imagery from DigitalGlobe provides adequate information for an initial analysis of the urban area of interest. Of the sites sampled, all had at least four quality images over the two-year sample period. This information would allow an analyst to deliver impactful situational insight for effectively planning possible courses of action (Table 3).

Table 3. Buckeye data comparison

Data Format	Baltimore	Maine	South Korea
GeoTiff	✓	✓	✓
Buckeye Imagery	✓	✓	✓
MrSID Imagery		✓	
Metadata file	✓	✓	✓

3 Road networks

3.1 Background

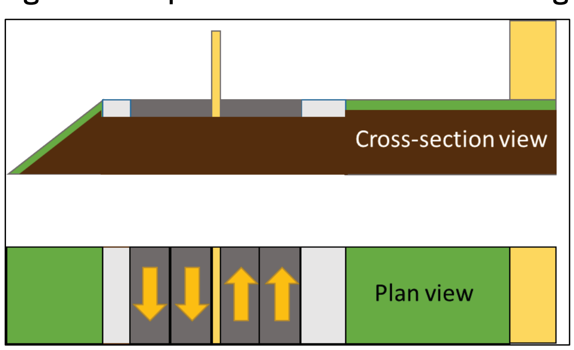
Accurate, well-attributed, and up-to-date road networks are essential to vehicle routing. Often geographic road data is stored as polyline features, rather than networks. Care must be taken to correctly connect these polylines to represent a network with appropriate overpasses and intersections. Given the difficulty in accurately automating this process, creating a road network from a set of roads intended only for display is a labor-intensive undertaking. Thus, it is preferable to use data sources that include road connectivity information natively. It is anticipated that many of the desired attributes may be unavailable, requiring data inference to close data gaps.

3.2 Desired attribute data

Representation of roads for routing requires not only the locations and connections of road segments but also the attributes to describe the road. For MCUE, the road surface and its surroundings have been divided into four basic categories.

The first category is the most obvious, namely the road surface intended for traffic movement. Second, the road may have improved shoulders beside the primary lanes. A third category includes open areas beside the road, which may or may not be favorable for vehicle traffic. The fourth category accounts for medians and lane separations. The goal of this representation is to allow the MCUE system to reroute vehicles around obstacles that block the normally intended traffic lane (Figure 11).

Figure 11. Representation of roads for routing.



3.2.1 Road surface

Key attributes for each road lane are

- Width
- Surface material (asphalt, concrete, gravel, dirt)
- Surface condition (roughness, strength)
- Travel direction
- Speed limit

3.2.2 Shoulders

Key attributes for each shoulder are

- Width
- Surface material (asphalt, concrete, gravel, dirt)
- Surface condition (roughness, strength)
- Travel direction of associated lane

3.2.3 Lane separations

Key attributes for each lane separation or median are

- Width
- Height
- Material
- Construction details to determine override potential

3.2.4 Open travel areas

Key attributes for each travel area are

- Width (to hard obstacle)
- Surface material
- Surface condition (roughness, strength)
- Travel direction of associated lane
- Lateral slope

3.2.5 Other features of interest

Other features of interest are

- Bridges
  - All road characteristics
  - Height and width limit
  - Military Load Classification (MLC)
- Obstacles
  - Geometry
  - Material
- Overhead obstructions
  - Height limit
  - Type (overpass, wires, etc.)

3.2.6 Segment properties

In addition to correctly attributing each category for each road node, some attributes will need to be considered by segment. Included in these are

- Curvature
- Visibility (as limited by static conditions)
- Longitudinal slope
- Connectivity to other segments

3.3 Urban Tactical Planner

Urban Tactical Planner is a vector dataset from AGC that consists of 23 separate folders of data.

Key Features (Cultural) – The folder includes data about key cultural facilities in the city, including cultural buildings, cemeteries, etc.

Key Features (Operationally Significant) – The folder includes data that could possibly be important to an operation.

Key Features (Police-Government) – The folder includes data about government and police buildings in the city.

Key Features (Landmarks) – The folder includes data about the monuments and navigational markers in the city.

Vertical Obstructions (Points) – The folder contains data on high points in the area (Figure 12).

Figure 12. Example of data for a vertical obstruction.

Building, 70 meters above ground level

Urban Tactical Planner Attributes

FAC_Code	AL015
Feature	Building
FeatureDescription	A relatively permanent structure, roofed and usually walled and designed for some particular use. (See also AL100)
Comments	SILO
BuildingSuperstructure	Other
Elevation	73 meters
Existence	Operational
Height	70 meters
MaterialComposition	Metal
TowerType	Not Defined
Source	Imagery/SRTM2
SecurityClassification	Unclassified
Releaseability	1

Information Pages – These are hyperlinks that will send the user to a website for further information on the area.

Ground Photos – Contains ground photos that could contain topographical details or other information.

Roads – Includes data about roads in the city including but not limited to number of lanes, location, road surface, surface materials, usage, width of lanes, and more (Figure 13).

Figure 13. Example of data for a road.

2 Lane, Asphalt, Unknown Road

Urban Tactical Planner Attributes

FAC_Code	AP030
Feature	Road
FeatureDescription	An open way maintained for vehicular use.
Existence	Operational
Lanes	2
Location	On Ground Surface
RoadSurface	Hard/Paved
SurfaceMaterial	Asphalt
Usage	Unknown
WeatherType	All Weather
Width	8 meters
Source	Imagery
SecurityClassification	Unclassified
Releaseability	2

Railroads – Railroads in this folder are separated into branch lines and main lines and include the following data: location, category, gauge, power source, siding or spur, and track arrangement.

Bridges – This folder contains data on bridges and includes length of bridge, location, material composition, surface material, surface types, transportation use, width, bridge span mobility, and bridge span superstructure.

Runways – This folder contains runway data including; feature, length, road surface, surface material, and width.

Water/Lines – This folder contains all of the waterways that run through the city including parameters such as: feature, gap width, and hydrology.

Ridgelines – This folder includes data about high elevations in topography. Indicating bluffs, cliffs, escarpments.

Vertical Obstructions (lines) – This folder includes conveyors and power lines; data includes height.

Forest – This folder includes data on wooded areas. It tells if forest is opened or closed, and the type of trees in the forest.

Water – This folder includes data on lakes, ponds, harbors, rivers, and streams. Data included for the bodies of water includes: feature, hydrology, and water quality.

Open Urban Areas – This folder labels the open areas in the urban areas and tells their surface material.

Buildings of Interest – This folder contains information about certain buildings along with checkpoints, fortification, silos, historic sights, monuments, stadiums, tanks, and undefined areas (Figure 14).

Figure 14. Example of data for Buildings of Interest.

COMMODORE JOHN RODGERS ELEMENTARY SCHOOL (Educational Center)

Urban Tactical Planner Attributes

FAC_Code	AL015
Feature	Building
Description	A relatively permanent structure, roofed and usually walled and designed for some particular use. (See also AL100)
Name	COMMODORE JOHN RODGERS ELEMENTARY SCHOOL
RoofShape	Flat
Existence	Operational
BuildingFunction	School
Floors	2
EducationalBuilding	Educational Center
Height	6 meters
Source	Imagery/Previous UTP Edition
SecurityClassification	Unclassified
Releaseability	2

Built Up Terrain Zone (Residential) – This folder shows where the residential areas of the city are located. This folder is split into two different subfolders; 1–2 Stories and 3–4 Stories. Data included about these areas include: income group, existence, usage, spacing, and height.

Built Up Terrain Zone (Commercial) – This folder shows where the commercial areas of the city are located.

Built Up Terrain Zone (Institutional) – This folder shows the institutional areas of the city.

Built Up Terrain Zone (Industrial) – This folder shows the industrial areas of the city.

3.3.1 Baltimore Urban Tactical Planner

Key Features (Cultural) – This folder contains information about cultural buildings, cemeteries, golf courses, historic sites and points, parks, swimming pools, and tennis courts.

Key Features (Operationally Significant) – This folder contains data on airport airfields, airport lighting, apron hardstand, athletic fields, basins, breakwaters, buildings, buoys, checkpoints, communication buildings, culverts, depot storage, disk dish, dolphins, dry-docks, floating docks, fortifications, grain bins, helicopter landing pads, leading lights, moles, not defined tab, oil and gas facilities, overrun stop way, pier wharfs and quays, power plants, quarries, radar transmitters, railroad turntables, railroad yard, reservoir, runways, runway endpoints, stadium/amphitheaters, substation/transformer yards, subways, tanks, vehicle storage/parking areas, water towers.

Key Features (Police-Government) – The only tab in this folder is buildings.

Key Features (Landmarks) – Subfolders include data about monuments and navigational marks/floats.

Vertical Obstructions (Points) – Subfolders include buildings, chimney/smokestacks, communication towers, cranes, flare pipes, monuments, not defined, power transmission/pylon, tower (non-communication), and water towers.

Information Pages – This includes hyperlinks for port information, city information and airport information.

Ground Photos – This includes a couple hundred pictures of important areas in the city

Roads – This folder contains information on hundreds of roads.

Railroads – This folder contains data on what looks like most if not all branch and main railroad lines.

Bridges – This folder contains basic data on what looks to be at least a couple hundred bridges in the city.

Runways – This folder contains a database of information on over 30 runways in the city.

Water/Lines – This folder contains data about 12 creeks, rivers, and streams within the city.

Ridgelines – This folder contains NO DATA.

Vertical Obstructions (lines) – This folder contains data about the cities conveyors and power transmission lines, including mainly data about the height of these obstructions.

Forest – This folder has information about the wooded areas in and around the city of Baltimore.

Water – This folder contains information on around 20 lakes and ponds in Baltimore

Open Urban Areas – This folder contains data on several open urban areas in the city.

Buildings of Interest – This folder contains information on buildings, checkpoints, communication buildings, fortifications, grain bin/silos, historic sites/point of interest, monuments, not defined, stadium/amphitheaters, and tanks.

Built Up Terrain Zone (Residential) – The subfolders split the residential zones into 1–2 story buildings, and 3–4 story buildings. These zones are also displayed as orange on Google Earth.

Built Up Terrain Zone (Commercial) – The subfolders split the commercial zones into 1–2 story buildings, 3–4 story buildings and 5–15 story buildings. These zones are also displayed as red on Google Earth.

Built Up Terrain Zone (Institutional) – The subfolders split the institutional zones into 1–2 story buildings, 3–4 story buildings and 5–15 story buildings. These zones are also displayed as purple on Google Earth.

Built Up Terrain Zone (Industrial) – The subfolders split the industrial zones into 1–2 story buildings, 3–4 story buildings, 5–15 story buildings, and 15+ story buildings. These zones are also displayed as yellow on Google Earth.

3.3.2 Moscow Urban Tactical Planner

Key Features (Cultural) – This folder contains information about cultural buildings, cemeteries, exhibition grounds, parks, ski tracks, tennis courts, swimming pools, and zoo/safari parks.

Key Features (Operationally Significant) – this folder contains data on aircraft bunkers, anchor berths, apron hardstands, athletic fields, buildings, communication buildings, communication towers, control towers, cranes, dam/weirs, disk/dish, grain bin/silos, harbors, helicopter landing pads, heliports, locks, overrun/stopways, piers/wharfs/quays, port facilities, power plants, processing/treatment plants, pumping stations, race tracks, railroad turntables, railroad/marshalling yards, reservoirs, runways, runway equipment, settling basins/sludge ponds, small aircraft facilities, stadiums/amphitheaters, substations/transformer yards, tanks, taxiways, non-communication towers, and waste processing facilities.

Key Features (Police-Government) – The only tab in this folder is buildings.

Key Features (Landmarks) – The subfolders in this folder include data about monuments, buildings, and stadiums/amphitheaters.

Vertical Obstructions (Points) – The subfolders include: chimney/smokestacks, communication towers, control towers, cooling towers, cranes, disk/dish, flare pipes, monuments, power transmissions/pylons, tower (non-communication), and water towers.

Information Pages – This contains hyperlinks to websites for seven airports and one for more information about Moscow.

Ground Photos – This folder contains NO DATA.

Roads – This folder contains NO DATA.

Railroads – This folder contains NO DATA.

Bridges – This folder contains NO DATA.

Runways – This folder contains a database of information on dozens of runways in Moscow.

Water/Lines – This folder contains NO DATA.

Ridgelines – This folder contains NO DATA.

Vertical Obstructions (lines) – This folder contains data on power transmission lines.

Forest – This folder contains NO DATA.

Water – This folder contains NO DATA.

Open Urban Areas – This folder contains data on several open urban areas in the city.

Buildings of Interest – The folder contains information on aircraft bunkers, buildings, communication buildings, control towers, disks/dishes, monuments, power plants, stadiums/amphitheaters, tanks, and waste processing facilities.

Built Up Terrain Zone (Residential) – The subfolders split the residential zones into 1–2 story buildings, 3–4 story buildings, and a not defined subfolder. These zones are also displayed as orange on Google Earth.

Built Up Terrain Zone (Commercial) – The subfolders split the commercial zones into 1–2 story buildings, 3–4 story buildings, and a not defined subfolder. These zones are also displayed as red on Google Earth.

Built Up Terrain Zone (Institutional) – The subfolders split the institutional zones into 1–2 story buildings, 3–4 story buildings, and a not defined subfolder. These zones are also displayed as purple on Google Earth.

Built Up Terrain Zone (Industrial) – The subfolders split the industrial zones into 1–2 story buildings, 3–4 story buildings, and a not defined subfolder. These zones are also displayed as yellow on Google Earth.

3.3.3 Sao Paulo Urban Tactical Planner

Key Features (Cultural) – The folder contains information about amusement parks, botanical gardens, buildings, cemeteries, croplands, exhibition grounds, fairgrounds, general miscellaneous features, golf courses, golf driving ranges, nurseries, orchard plantations, parks, plazas/city squares, swimming pools, tennis courts, and zoo/safari parks.

Key Features (Operationally Significant) – This folder contains data on aircraft bunkers, airport airfields, apron hardstands, athletic fields, buildings, checkpoints, communication buildings, control towers, culverts, dams/weirs, depot storage, disks/dishes, disposal/waste sites, feed lots/stockyards, filtration beds/aeration basins, gates, grain bin/silos, helicopter landing pads, heliports, not defined tab, oil and gas facilities power plants, processing plants/treatment plants, pumping stations, quarries, race tracks, railroad yard/marshalling yards, reservoirs, runways, runway endpoints, settling basins/sludge ponds, sluice gates, solar panels, spillways, stadium/amphitheaters, substations/transformer yards, tanks, taxiways, non-communication towers, tunnels, underground bunkers, rest areas, parking areas, waste processing facilities, water towers, and wrecking/scrap yards.

Key Features (Police-Government) – The subfolders include data on buildings, military bases, and non-communication towers.

Key Features (Landmarks) – The subfolders include data on fountains and monuments.

Vertical Obstructions (Points) – The subfolders include chimney/smokestacks, communication towers, control towers, cooling towers, cranes, flare pipes, monuments, not defined folder, power transmission/pylons, non-communication towers, and water towers.

Information Pages – This includes three airport hyperlinks, five heliport hyperlinks, and a hyperlink to a website about the city of Sao Paulo.

Ground Photos – This includes a couple dozen pictures of important areas in the city.

Roads – This folder contains data on hundreds of roads in the city. The folder is broken up into interstates, primary, 1st order, and secondary, 2nd order.

Railroads – This folder contains data on what looks like most if not all branch, main, monorail, other, and unknown railroad lines.

Bridges – This folder contains basic data on what looks to be at least a few hundred bridges in the city.

Runways – This folder contains a database of information for about 50 runways in the city. The folder is broken into civilian public and joint military and civilian runways.

Water/Lines – This folder contains data on hundreds of ditches, creeks, rivers, and streams within the city.

Ridgelines – This folder contains elevation data on the highest topography within the city.

Vertical Obstructions (lines) – This folder contains data about the cities conveyors, pipelines, and power transmission lines; mainly data about the height of these obstructions.

Forest – This folder includes information about the wooded areas in and around the city of Sao Paulo.

Water – This folder contains information on hundreds of marshes, lakes, and ponds in Brazil, along with possible flood plain areas.

Open Urban Areas – This folder contains data on several open urban areas in the city.

Buildings of Interest – This folder contains information on buildings, communication buildings, control towers, depots/storage, grain bins/silos, not defined subfolder, power plants, processing/treatment plants, stadiums/amphitheaters, tanks, non-communication towers, and underground bunkers.

Built Up Terrain Zone (Residential) – The subfolders split the residential zones into 1–2 story buildings, 3–4 story buildings, and 5–15 story buildings. These zones are also displayed as orange on Google Earth.

Built Up Terrain Zone (Commercial) – The subfolders split the commercial zones into 1–2 story buildings, 3–4 story buildings, and 5–15 story buildings. These zones are also displayed as red on Google Earth.

Built Up Terrain Zone (Institutional) – The subfolders split the institutional zones into 1–2 story buildings, 3–4 story buildings, and 5–15 story buildings. These zones are also displayed as purple on Google Earth.

Built Up Terrain Zone (Industrial) – The subfolders split the industrial zones into 1–2 story buildings, 3–4 story buildings, 5–15 story buildings and 15+ story buildings. These zones are also displayed as yellow on Google Earth.

3.3.4 Data comparison

The selected datasets were updated on the dates below

- Baltimore (04/06/2015)
- Moscow (04/27/2015)
- Sao Paulo(06/21/2016)

Table 4 shows a summary of the attributes that were provided in each dataset. Not all cities have equally attributed features. Table 5 shows a checklist of desired road attributes available for the three selected datasets.

Table 4. Comparison of populated layers within Urban Tactical Planner datasets.

Data	Baltimore	Moscow	Sao Paulo
Bridges	X		X
Buildings of Interest	X	X	X
Builtup Terrain Zone (Commercial)	X	X	X
Builtup Terrain Zone (Institutional)	X	X	X
Builtup Terrain Zone (Residential)	X	X	X
Forests	X		X
Ground Photos	X		X
Information Pages	X	X	X
Key Features (Cultural)	X	X	X
Key Features (Landmarks)	X	X	X
Key Features (Operationally Signficant)	X	X	X
Key Features (Police/ Government)	X	X	X
Open Urban Areas	X	X	X
Ridgelines			X
Roads	X		X
Runways	X	X	X
Vertical Obstructions (Lines)	X	X	X
Vertical Obstructions (Points)	X	X	X
Water (lines)	X		X
Water (polygons)	X		X
X = Data is included in dataset.			

Table 5. Checklist of desired road attributes provided by Urban Tactical Planner.

Data	Baltimore	Moscow	Sao Paulo
Road Width	X		X
Number of Lanes	X		X
Road Surface Type	X		X
Overhead Restrictions	X	X	X
Bridge Data	X		X
Tunnels	X		X
Curvature Data	*		*
Road Slopes	*		*
Network Connectivity			

X = Dataset provides this attribute directly.

* = Dataset may assist in determining this attribute.

3.4 Engineering Route Study

The Engineering Route Study (ERS) datasets from AGC are intended to provide data at the country or operational level to assist the warfighter in planning a variety of missions including military operations, humanitarian relief, transportation studies, and drug enforcement. ERS datasets consist of Google Earth files, GIS shapefiles, and PDF files with compiled data about the region of interest. Some ERS datasets only contain PDF files.

3.4.1 Features

Below is a list of the types of data that can be found inside of the Engineering Route Study (ERS).

Boundaries – This folder includes data about boundaries within the area. Some types of boundaries that are included are Administrative Boundaries, Administrative Divisions, and Land/Water Boundaries.

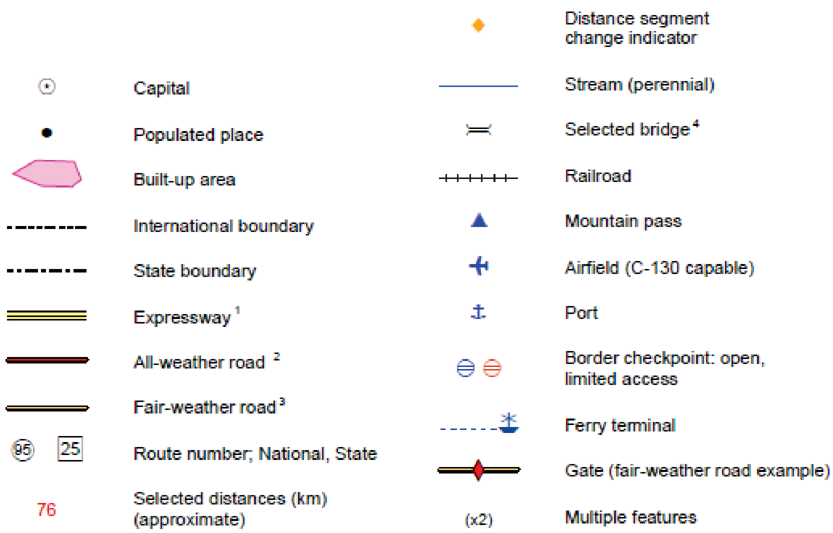
Cultural/Built Up Areas – This folder offers data about the urban regions within the Engineering Route Study.

Terrain – This folder includes data about the geography within the ERS. This folder includes information about waterbodies, rivers, surface, checkpoints, and land subject to inundation.

Transportation – This folder includes data about the methods of transportation within the ERS area. This data includes information about roads, railways, ports, ferry crossings, bridges, tunnels, etc.

A sample map legend from the Maine ERS PDF map is shown in Figure 15.

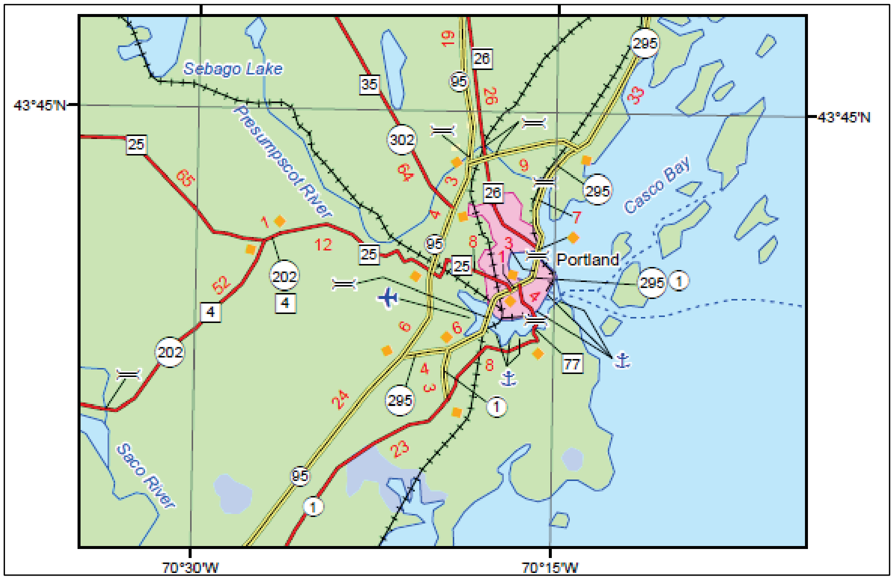
Figure 15. Sample map legend from the Maine ERS PDF map.



3.4.2 Comparison

ERS datasets for Maine, South Korea, and Costa Rica were examined. These datasets have limited detail and are suitable for understanding avenues of approach to an urban area, but not maneuver within the urban area itself. For example, Figure 16 shows the inset of Portland, Maine from the Maine ERS PDF.

Figure 16. Sample ERS data for Portland, Maine.



3.5 National System for Geospatial Intelligence (NSG) Open Mapping Enclave (NOME)

3.5.1 NOME Applications (Apps)

NOME provides data that was branched from the OpenStreetMap database and allows certain users to change and update data in real time. This includes data about roads, trails, railways, airstrips and other modes of transportation.

NOME includes fifteen different apps. These apps all contribute to the viewing, editing, and downloading of data.

<u>MapEdit</u> – MapEdit is a web based mapping application that allows users to contribute and maintain data about roads, trails, café railway stations, and much more, all over the world using high-resolution imagery.

<u>Tasking Manager</u> – MapEdit Tasking Manager (METM) enables collaborative work on specific areas in MapEdit by defining clear workflows to be achieved and by breaking tasks down into pieces. This application is used in collaboration with MapEdit.

<u>GeoNode</u> – GeoNode is a geospatial content management system, a platform for the management and publication of geospatial data for MapEdit. It brings together mature and stable open-source software projects under a consistent and easy-to-use interface allowing non

specialized users to share data and create interactive maps with the NGA and ASG.

<u>MapFeatures</u> – MapFeatures is a MapEdit wiki site that has a list of OpenStreetMap tags and feature descriptions to help MapEdit users identify appropriate OSM tags.

<u>TagInfo</u> – TagInfo shows statistics about which tags are used in the database. The goal is to bring together all information about tags to help better clarify how they are used in MapEdit and what they mean.

<u>Hootenanny</u> – Hootenanny is an open source tool to facilitate automated and semi-automated conflation of critical foundation Geospatial Intelligence (GEOINT) features in the topographic domain, namely roads (polylines), buildings (polygons), and points-of-interest (POI) (points).

<u>MapEdit Overpass Turbo</u> – Overpass Turbo is a web-based data filtering tool for OSM data for MapEdit users. The Overpass API queries and analyzes the results of OSM data and allows users to export the data into various formats.

<u>NOME Wiki</u> – NOME Wiki housing provides training for NOME applications, as well as any reference documentation. This is in development.

<u>OSQA</u> – OSQA (Open Source Question and Answer) is an open source question-answer system, similar to tools like Stack Overflow and AnswersHub.

<u>MapEdit-OSM Compare Tool</u> – The compare tool provides the ability to view MapEdit and OSM data side-by-side. There are also shortcuts to results from existing mapping campaigns.

<u>GeoJSON Tool</u> – The NOME GeoJSON tool is a quick and simple tool for creating and viewing a GeoJSON. The file can be created by uploading another geospatial file or creating by hand.

<u>Changeset Analyzer</u> – Searches for changes made by a particular user by specific dates.

Blog – Contains useful information about NOME. The blog allows users to communicate together and with NOME developers.

MapRoulette – This app shows open tasks available for the user to contribute.

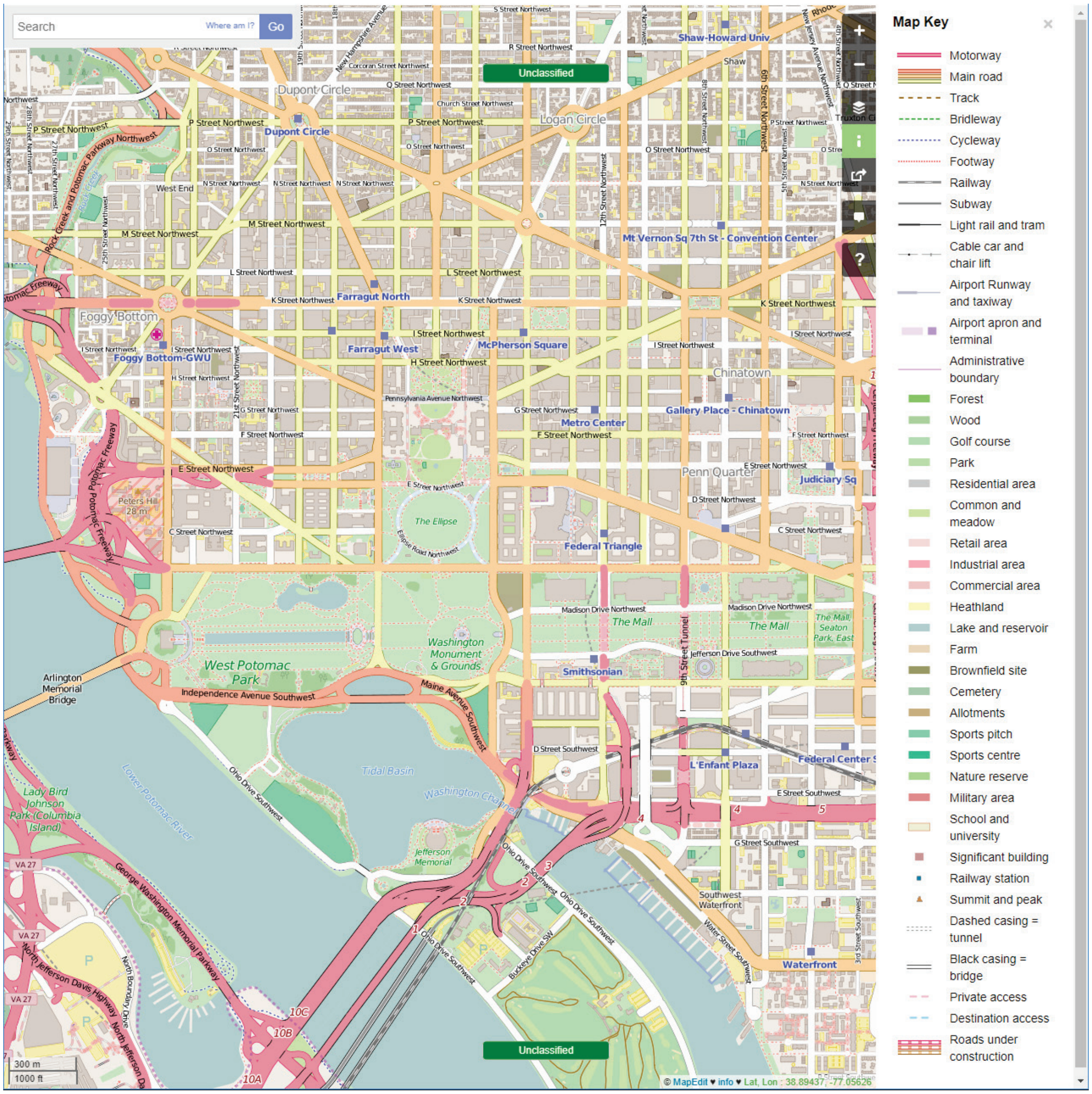
Nominatim – NOME's Nominatim is a search engine for MapEdit data.

MapEdit – MapEdit is the main app for NOME. It is used to view OpenStreetMap data along with changes that have been made by users and verified as correct (Figure 17).

Figure 17. MapEdit view of Washington, D.C; low level of detail shown at large scale.

The MapEdit app contains three different layers. The default layer is the MapEdit layer. This layer shows roadways and other defined areas within a certain region. It also includes a Map Key which is a dynamic legend for the map. As the user zooms in and out, the Map Key will show different items on the legend (Figure 17 and Figure 18).

Figure 18. MapEdit view of Washington, D.C., zoomed in to show additional features.



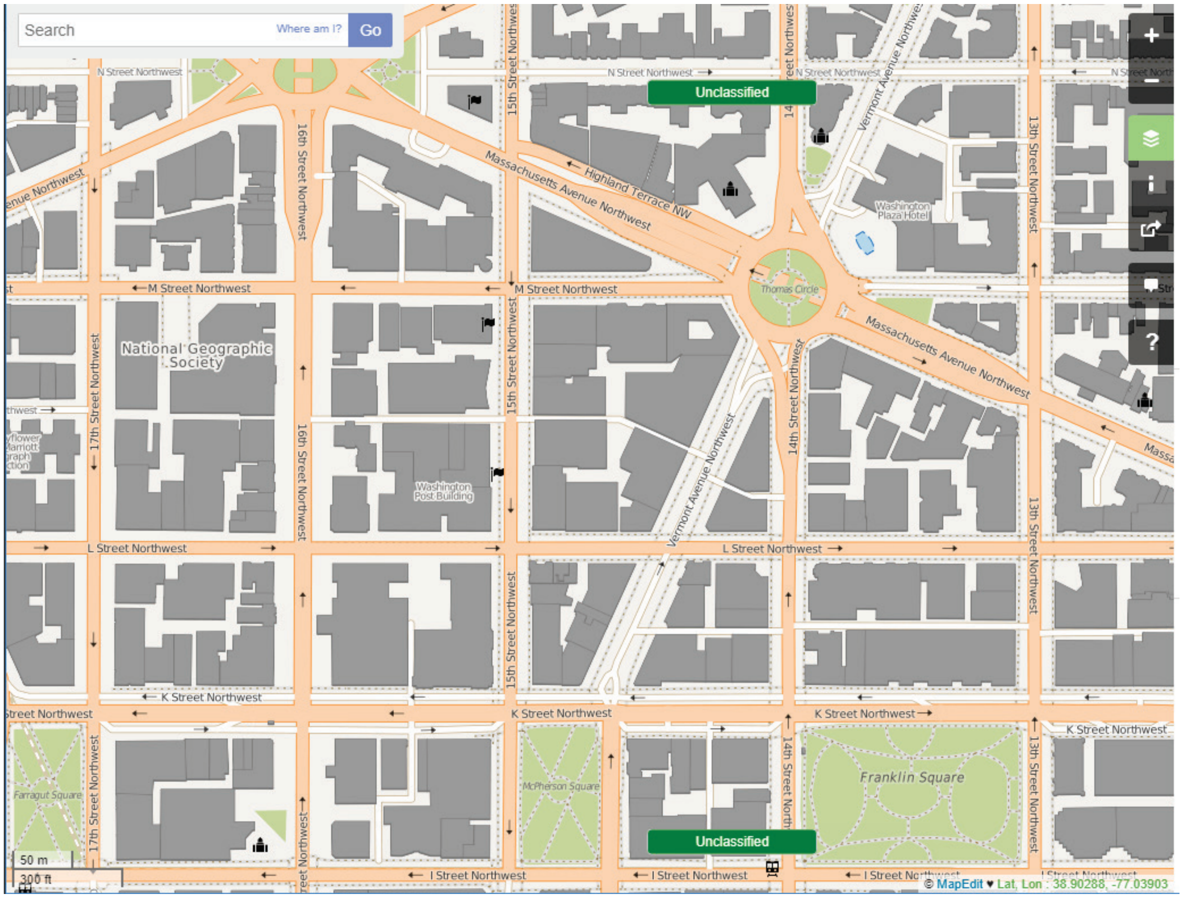
In addition to the MapEdit layer (Figure 19), users can also view the NGA topographic layer (Figure 20) and DigitalGlobe imagery (Figure 21). The Map Key is not available on the NGA topographic or DigitalGlobe layers.

MapEdit also allows the user to overlay data in the following formats: GeoJSON, WMS, Geonode, and TMS\WMTS.

Figure 19. Sample MapEdit layer.

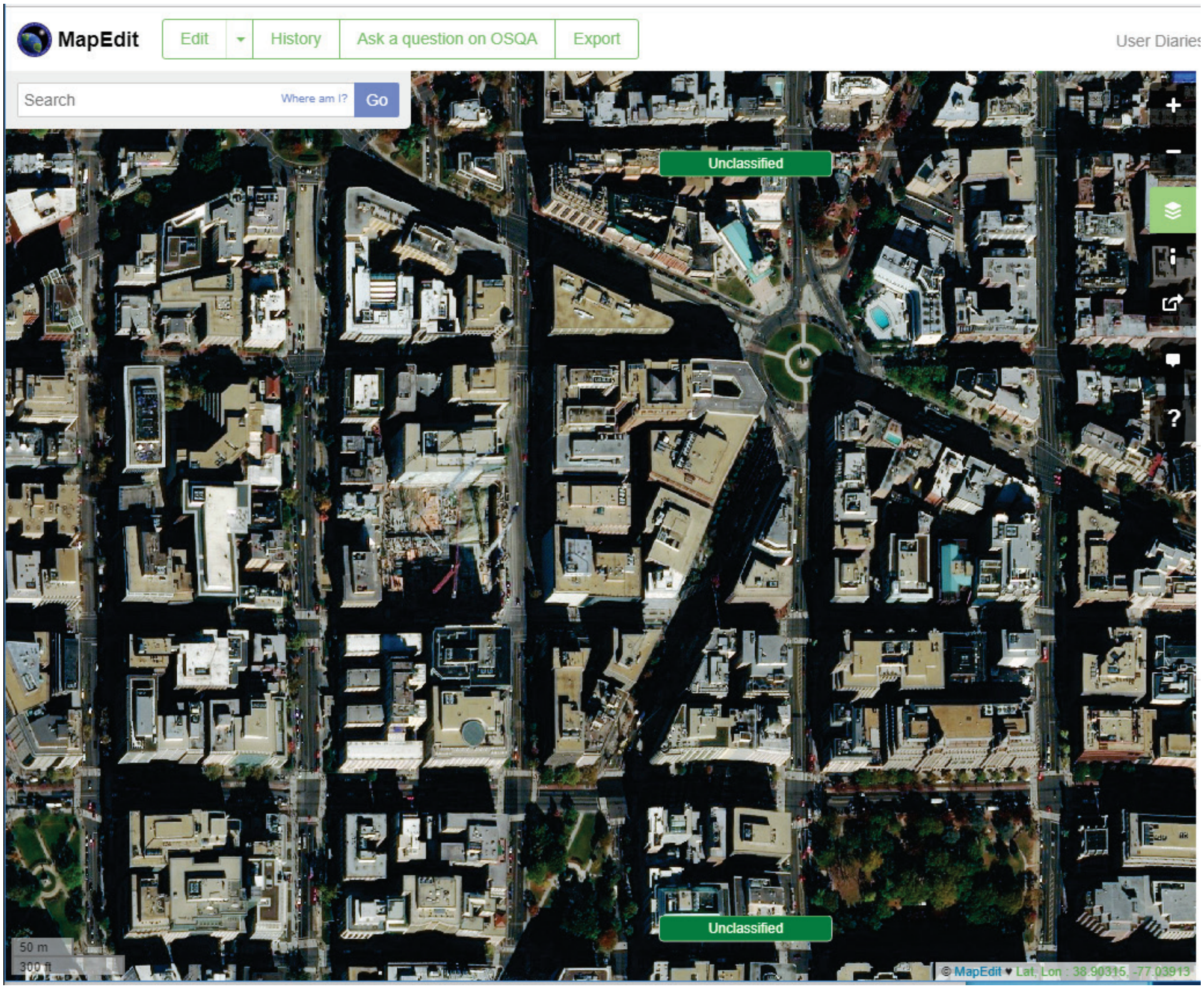
Figure 19 shows the detail displayed in the MapEdit layer. Along with the items that are listed in the Map Key, the layer also includes: street names, traffic direction, locations of street lights, building footprints, building addresses, and names of buildings and businesses. The NGA topographic layer (Figure 20) shows street names, traffic direction, building footprints, street locations, and a few names of buildings.

Figure 20. Sample NGA topographic layer.



The DigitalGlobe layer (Figure 21) shows the detail displayed in the MapEdit layer. Along with the items that are listed in the Map Key, the layer also includes: the unclassified DigitalGlobe Imagery.

Figure 21. Sample DigitalGlobe layer.



3.5.2 Comparison of MapEdit areas

The Comparison of MapEdit Areas (Table 6) is a summary of the available data that can be extracted from the datasets.

Table 6. Comparison of MapEdit areas.

Data	Baltimore	Moscow	Seoul	Pyongyang	Muscatatuck	Demascus	Washington, D.C.	San Jose
Road Width								
Number of Lanes	Limited	Limited	Limited	Limited		Limited	Limited	Limited
Road Surface Type								
Overhead Restrictions								
Bridge Data								
Tunnels	Location	Location					Location	
Curvature Data	*	*	*	*	*	*	*	*
Road Slopes	*	*	*	*	*	*	*	*
Network Connectivity	X	X	X	X	X	X	X	X

3.6 Conclusion

NOME appears to be the best dataset to pursue at this time. It contains network connectivity information and has a detailed schema for road attributes. As usage increases, this dataset will grow with user-submitted data. At present, much of the globe is covered with at least minimal road network data (road location and road type).

Where UTP datasets are available, they offer more attribute data and higher confidence in the standardization of the data. However, these datasets are only available for select urban areas.

ERS shares some attributes with UTP, but ERS has broader spatial coverage and less detail. ERS datasets provide relatively coarse route information that has limited utility for complex urban environments.

4 Elevation Data

4.1 Background

Elevation data is necessary to understand the complex nature of urban terrain. It can be used to compute slopes along roads and to identify built-up areas.

4.2 Desired data

Like imagery, elevation data also comes in various resolutions. Two important considerations for elevation data are the spatial resolution and the vertical resolution. As with imagery, spatial resolution for an elevation raster can be expressed in terms of pixel size. Vertical resolution refers to the level of precision used in expressing the elevation values. Generally, elevation datasets with higher spatial resolution will also have higher vertical precision and accuracy. For instance, a spatially coarse elevation map may express elevation as integer values in meters.

Elevation data can also be stored in several formats. Two of the most common forms are rasters (uniform square or rectangular grids with one elevation value per pixel) and point clouds (collections of points located in three dimensional (3D) space). Each of these types has its own advantages and disadvantages. However, rasters are more commonly available for large areas and are the focus for this report.

Another key attribute of elevation data is which surface is represented by the data. Data can be either the surface as detected by a sensor, which includes trees, buildings, and other features, or it can be bare earth data, which means that some filtering has been performed to remove those features so that the ground surface itself is represented. For MCUE, both types could provide information. A pre-processed bare earth dataset is expected to give better road slope for roads built on the ground surface. However, a surface map that includes man-made features would provide better information about building footprints, building heights, and other items of interest.

4.3 Digital Terrain Elevation Data (DTED)

NGA’s longstanding elevation standard is the Digital Terrain Elevation Data (DTED). DTED is available in varying levels of spatial resolution. The coarsest is Level 0 (nominally 1 km), mid-range is Level 1 (nominally 100 m), and the finest is Level 2 (nominally 30 m). The coverage of these datasets decreases as the spatial resolution increases, as shown in Figures 22–24. DTED Level 0 (Figure 22) covers the globe. DTED Level 1 (Figure 23) covers most of the world but is missing large areas. DTED Level 2 (Figure 24) has much smaller coverage area.

Figure 22. Global coverage of DTED Level 0.

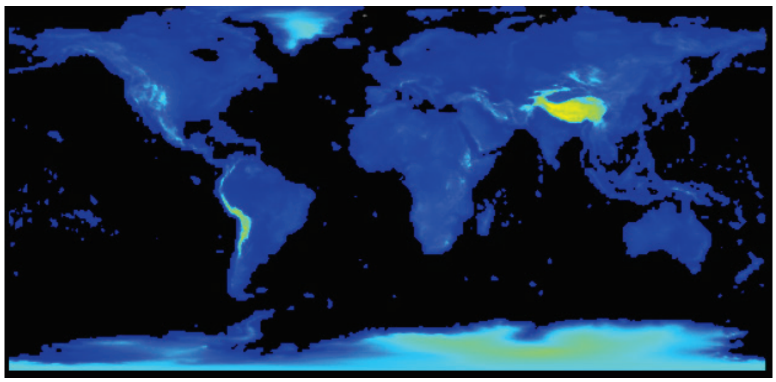


Figure 23. DTED Level 1 coverage.

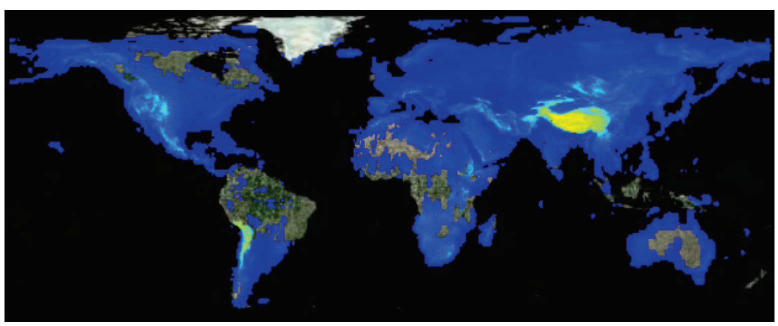
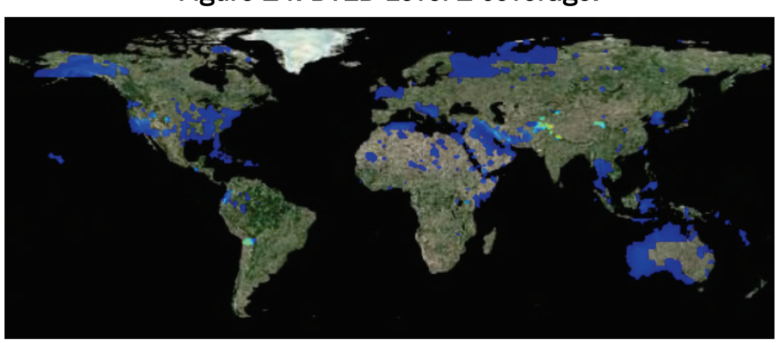


Figure 24. DTED Level 2 coverage.



4.4 Shuttle Radar Topography Mission (SRTM)

The Shuttle Radar Topography Mission (SRTM) elevation data was collected in the year 2000 via the space shuttle and was released in 2015. This data was processed into two layers, one at 90 m resolution and one at 30 m resolution. Both datasets cover about 80% of the world's land, the only missing areas above 60° N or below 56° S latitude (Figures 25 and 26).

Figure 25. SRTM 90 m coverage.

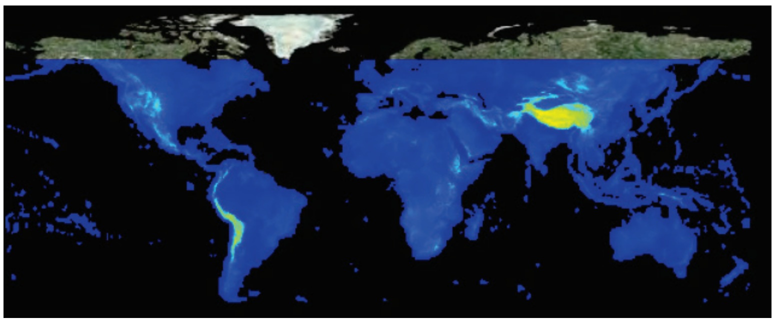
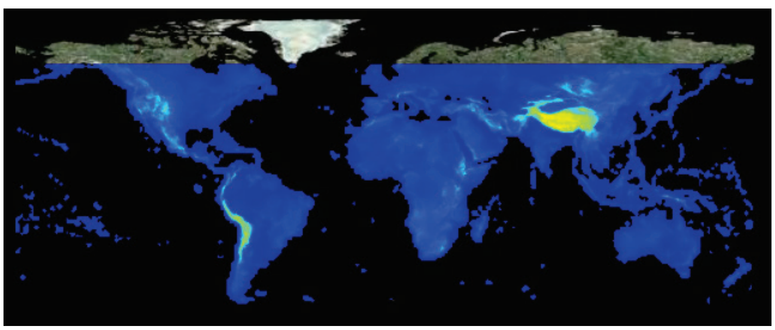


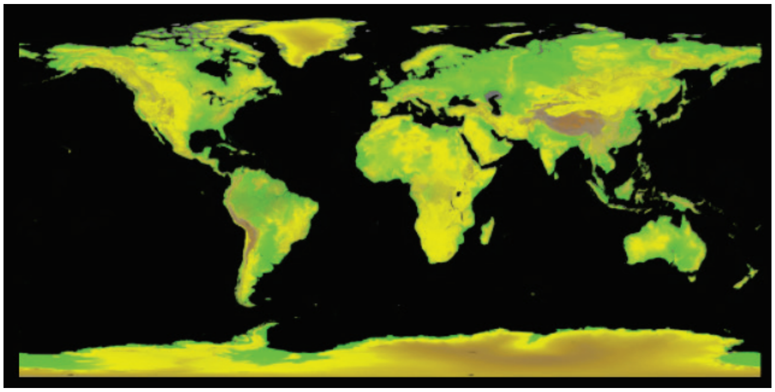
Figure 26. SRTM 30 m coverage.



4.5 TanDEM-X High Resolution Data Exchange (TREx)

TanDEM-X is a new elevation dataset (completed in September 2016) that provides 12 m resolution coverage of the entire world (Figure 27).

Figure 27. TanDEM-X global coverage.

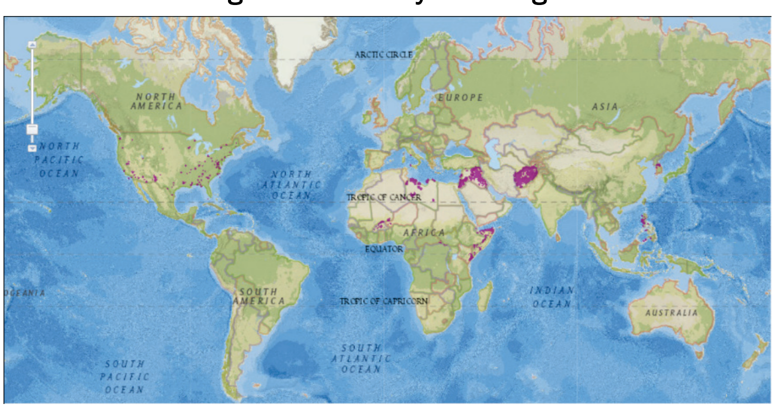


4.6 Buckeye Data

As mentioned in section 2.4, AGC's Buckeye dataset includes both imagery and elevation data. The Buckeye elevation data consists of point cloud formatted (LAS/LAZ) data and its corresponding derived raster formatted (geotiff) data. The raster imagery data is available from AGC's website for direct download as discussed in section 2,4; the point clouds can be requested from the point of contact listed on the AGC website.

LiDAR data has been prepared for certain areas within the following regions: Afghanistan, Burkina Faso, Columbia, Djibouti, Haiti, Iran, Iraq, Jordan, Kenya, Korean Peninsula, Niger, Philippines, Senegal, Seychelles, Somalia, United Arab Emirates, United States of America, and Yemen (Figure 28).

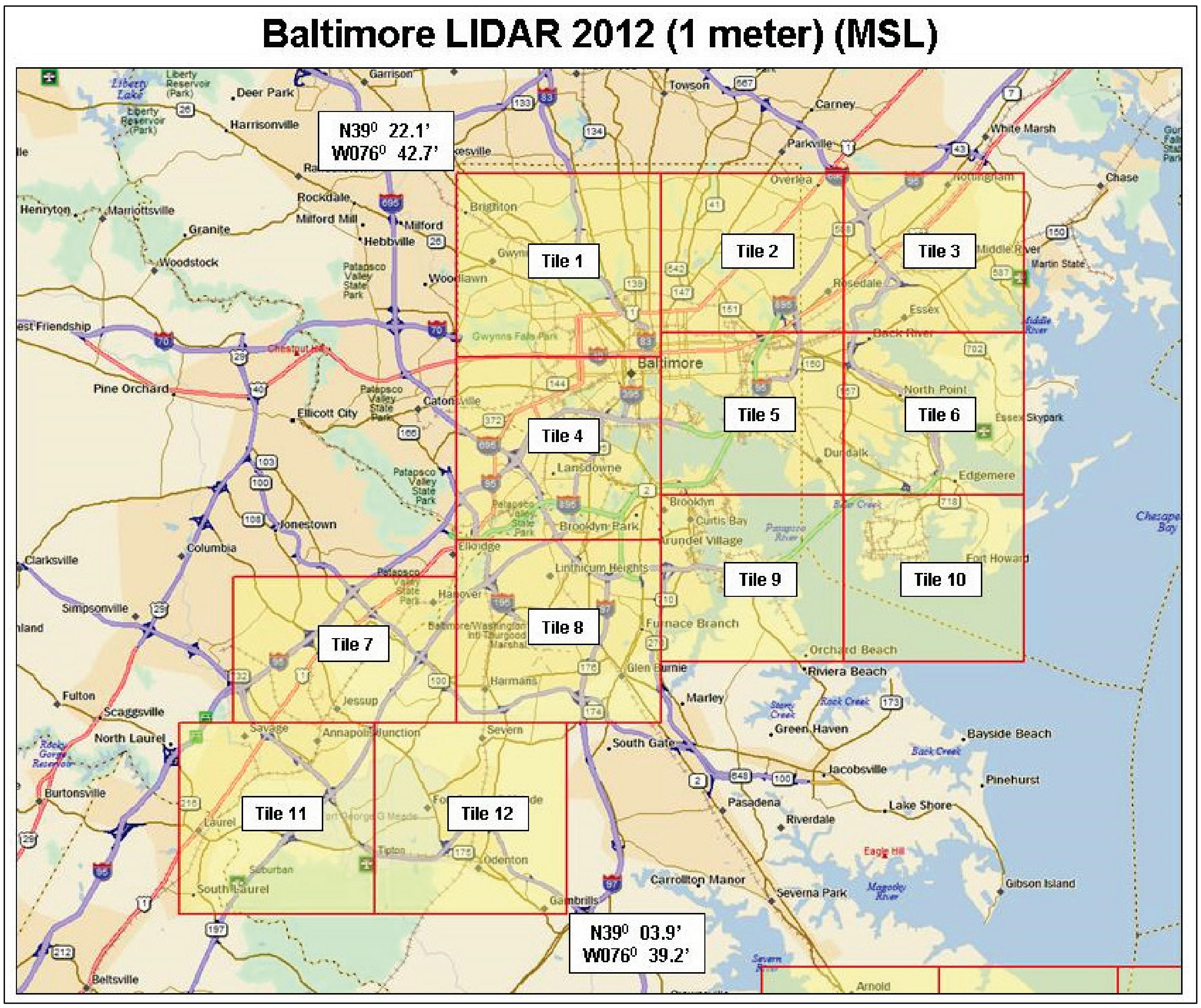
Figure 28. Buckeye coverage.



4.6.1 Baltimore Buckeye

The first step to analyzing the Baltimore Buckeye study is to open the folder for USA (https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/US), then open the folder for Maryland, and finally open the Baltimore folder. The Baltimore folder contains many different folders. First, open the .jpg file that shows the LiDAR Index for Baltimore. This file will show which tile within the location to be analyzed is located in. Once the tile is located that encompasses the area to be analyzed, open the file to that tile. For this study, the files and extractable data located in the Tile 1 folder will be analyzed (Figure 29).

Figure 29. Baltimore LiDAR index.



The file types inside the Tile 1 folder include the following:

GeoTiffs:

Two DEMs that include buildings and vegetation along with topographical data collected from LiDAR.

One DEM that only includes topographical data. This type of DEM is also known as a bare surface model (Figure 30).

Two, 2D tiff files that consist of imagery, which can be draped over the DEMs to add imagery, are discussed in section 2.4 (Figure 31).

Figure 30. Bare surface DEM (viewed in QTReader).

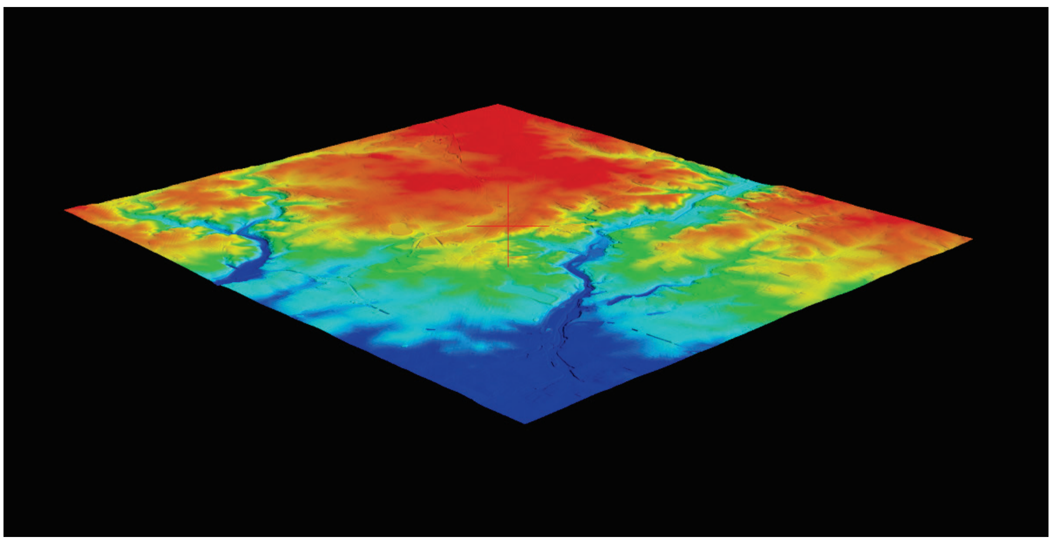
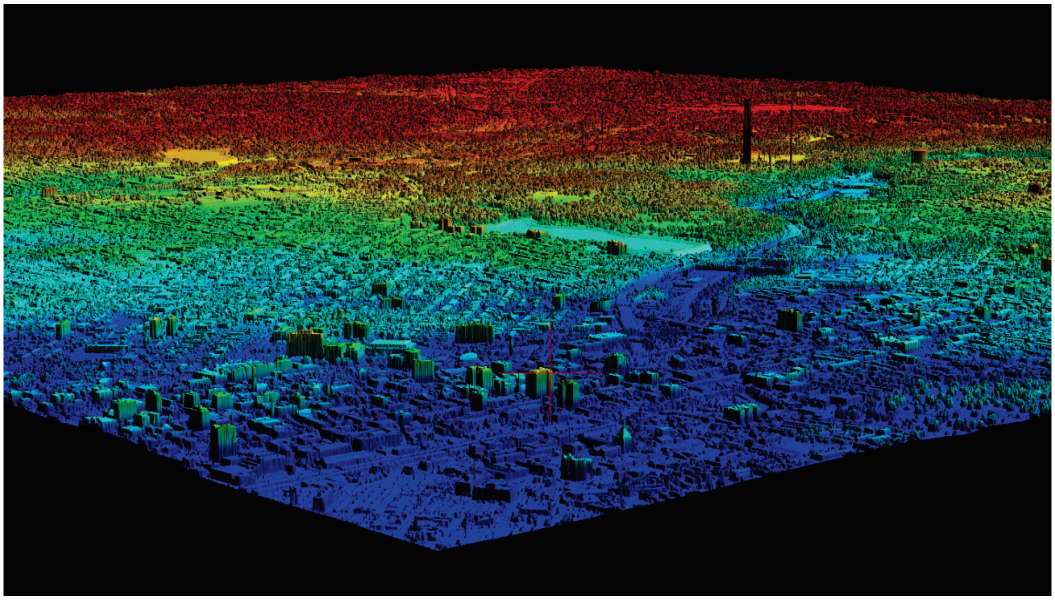


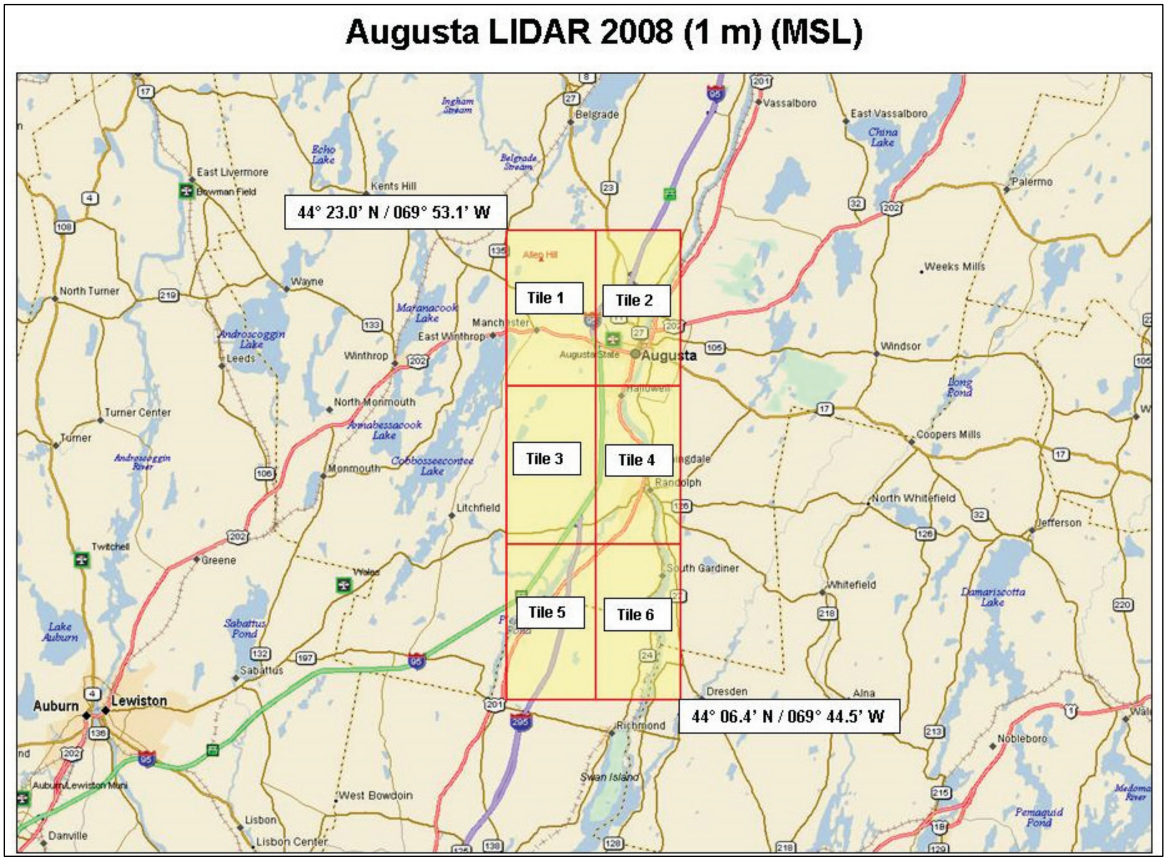
Figure 31. DEM with buildings and vegetation.



4.6.2 Maine Buckeye

The first step to analyzing the Maine Buckeye study is to open the folder for USA (https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/US), and then open the folder for Maine. Inside the Maine folder there are three different study areas. The three concentration areas of the Maine Buckeye study are Augusta, Callahan Mine, and the Maine border. First, this study analyzed the Augusta ME folder. Inside of the Augusta folder are many different folders. First, open the .jpg file that will show the Lidar Index for Augusta. This file will show which tile the location to be analyzed is located in. Then once the tile that encompasses the area to be analyzed is chosen, open the file to that tile. For this study, the files and extractable data located in the Tile 1 folder will be analyzed (Figure 32).

Figure 32. Augusta LiDAR index.



The file types inside the Tile 1 folder include the following:

<u>GeoTiffs:</u>

Two DEMs that include buildings and vegetation along with topographical data collected from Lidar.

One DEM that only includes topographical data. This type of DEM is also known as a bare surface model (Figure 33).

Two, 2D tiff files that consist of imagery, which can be draped over the DEMs to add imagery, are discussed in section 2.4 (Figure 34).

Figure 33. Augusta bare surface DEM.

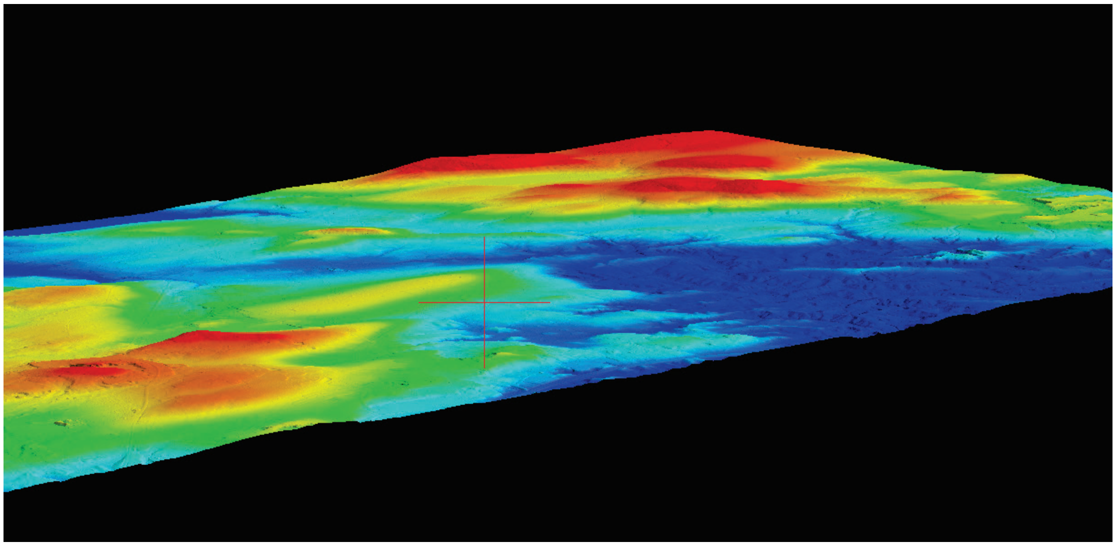
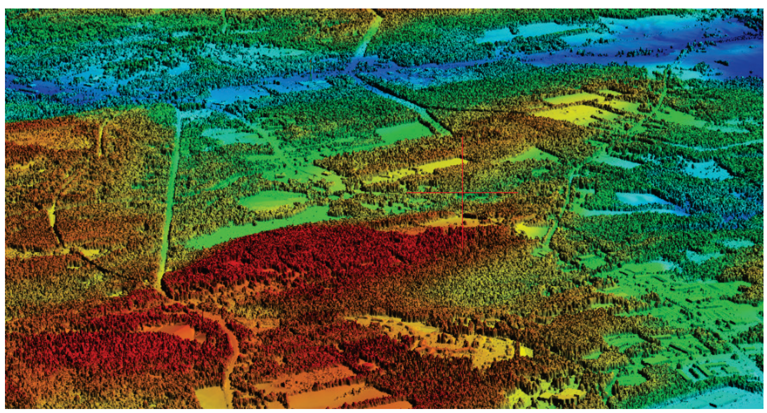


Figure 34. Augusta DEM with buildings and vegetation.

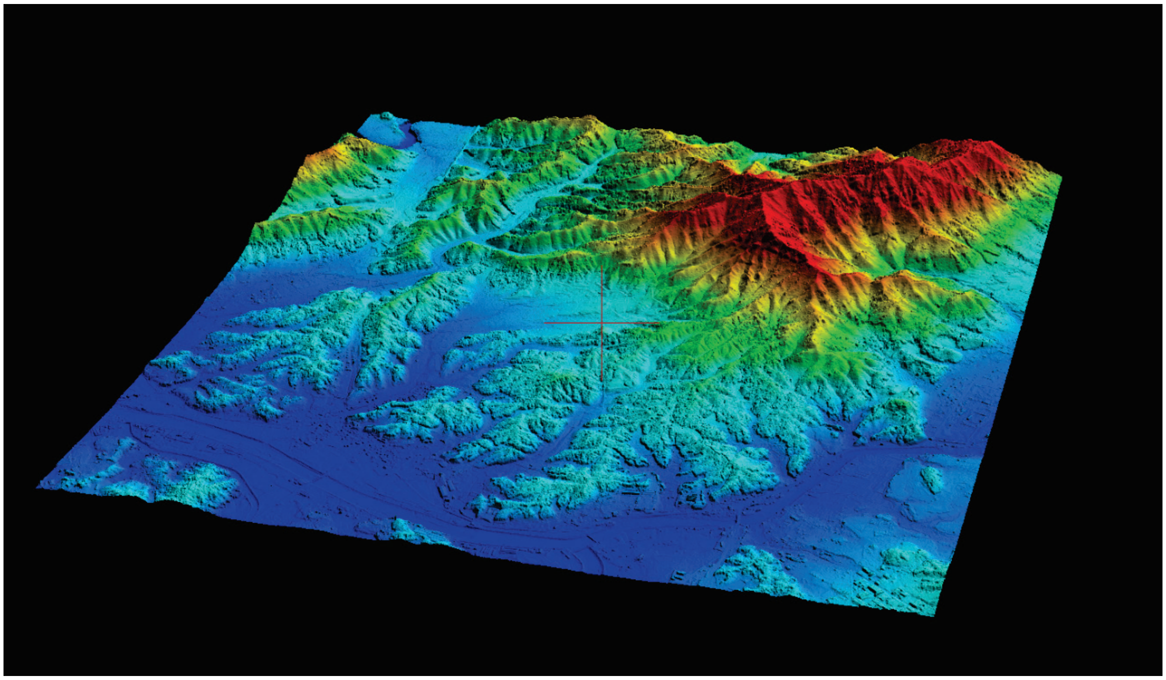


4.6.3 South Korea Buckeye

The first step to analyzing the South Korea Buckeye study is to open the folder for the Korean Peninsula (https://cac.agc.army.mil/Products/filelib.cfm?d=/lidar/Korea), and then open the folder for South Korea Vricon Rodriguez Range. Inside of the South Korea Vricon Rodriguez Range folder there are two subfolders. The two subfolders are South Korea Vricon DSM WGS84 Rodriguez Range and South Korea Vricon True Ortho Rodriguez Range.

Inside of the South Korea Vricon DSM WGS84 Rodriguez Range there are four GeoTiff files that when opened simultaneously in the QTReader, show the entire digital surface model of the Rodriguez Range (Figure 35).

Figure 35. Rodriguez Range (South Korea) GeoTiff digital surface model.



Inside of the South Korea Vricon True Ortho Rodriguez Range folder there are four .tex.tif files that correspond with each of the four GeoTiff files. The tex.tif files include high quality color imagery that can be draped over the GeoTiff digital surface model. Once the imagery has been draped over the digital surface model, the new digital surface model will show terrain along with imagery. Also included in this folder is a metadata.json file that includes some data about the tex.tif files, but this file must be opened in ArcCatalog to view all of the metadata.

4.6.4 Buckeye data comparison

The Buckeye data comparison (Table 7) is a summary of the available data formats that are available.

Table 7. Buckeye data comparison.

Data Format	Baltimore	Maine	South Korea
GeoTiff	✓	✓	✓
Buckeye Imagery	✓	✓	✓
MrSID Imagery		✓	
Metadata file	✓	✓	✓

4.7 Summary

TanDEM-X appears to be the best available worldwide dataset, with a resolution of 12 m (Table 8). Thus, it is recommended that TanDEM-X be considered the baseline, and higher resolution datasets should be used where available.

Table 8. Summary comparison.

Data Source	Pixel Size (m)	Relative Vertical Accuracy (<20% Slope)	Relative Vertical Accuracy (>20% Slope)	Bare Earth Available?	Surface Available?	Coverage
DTED Level 0	1000	20	N/A	No	Yes	Worldwide
DTED Level 1	100	20	N/A	No	Yes	Most of the world
DTED Level 2	30	12 m	15 m	Yes	Yes	Spotty
SRTM 90	90	15 m	20 m	No	Yes	+/- 60° latitude; most of the world
SRTM 30	30	10 m	16 m	No	Yes	+/- 60° latitude; most of the world
TanDEM-X	12	2 m	4 m	No	Yes	Worldwide
Buckeye	1	0.05	0.1	No	Yes	Limited

5 Conclusions and Recommendations

As expected, the existing off-the-shelf geospatial data provides a starting point for urban terrain analysis. This includes imagery, road networks, and elevation data.

For imagery, it is recommended that WorldView imagery from DigitalGlobe be used both for a map background for user reference and for initial object detection efforts. This data is relatively high resolution (sub-meter for panchromatic and about 2 m for multi-spectral).

For road networks, NOME is recommended as the initial data source. Unfortunately, many of the desired road attributes may be missing. However, road network data is expected to improve as the NOME database matures and authorized users submit more data.

For elevation data, TanDEM-X is recommended as the primary dataset, as it has relatively high resolution (12 m) across the entire globe. Where there is coverage available from a higher resolution dataset such as Buckeye, that data should be used instead.

As the Army's geospatial resources develop, it will be necessary to investigate new datasets to understand their benefits and limitations in the context of urban operations.

References

Digital Globe. nd. Accessed on 19 March 2019. https://www.digitalglobe.com.

Headquarters, Department of the Army. 2003. *Urban Operations* (FM 3-06). https://www.bits.de/NRANEU/others/amd-us-archive/fm3-06%2803%29.pdf.

Headquarters, Department of the Army. 2002. *Combined Arms Operations in Urban Terrain* (FM 3-06.11). https://fas.org/irp/doddrir/army/fm3-06.pdf.

Liang, S., X. Li, and J. Wang. 2012. *Advanced Remote Sensing*. Ch. 1 "A Systematic View of Remote Sensing." Oxford, UK: Academic Press.

National Geospatial Intelligence Agency (NSG) nd. *Open Mapping Enclave*. (Accessed on 5 April 2019) https://home.geointservices.io/

U.S. Army Geospatial Research Center. nd. *Buckeye Imagery Library*. Accessed on 19 March 2019. https://cac.agc.army.mil/Products/BuckEye/index.cfm.

U.S. Army Geospatial Research Center. nd. *Engineering Route Study ERS Product Library*. https://cac.agc.army.mil/Products/EngineeringRouteStudies/index.cfm.

U.S. Army Geospatial Research Center. nd. *Urban Tactical Planner Product Laboratory*. https://cac.agc.army.mil/Products/UTI/index.cfm.

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14. ABSTRACT
Real-time urban mobility modeling presents a unique challenge in the area of terrain representation. The terrain must be sufficiently detailed to depict real limitations on vehicle movement, but it must also be transmitted, stored, and processed efficiently enough to allow rapid mobility estimates in a moving vehicle. Moreover, urban environments have different mobility limitations than off-road environments. The primary limitation to mobility in urban areas is expected to be geometry, which includes roadway width, intersection configurations, and overhead restrictions. Additional limits may be caused by static and dynamic obstacles and by bridge capacity limits, which are commonly expressed in terms of Military Load Classification (MLC). Local traffic control measures (e.g., stop signs, traffic lights) may also need to be considered, depending on the desired operation procedures. The goals of this report are to summarize the available baseline geospatial datasets for use in mobility analysis of urban areas and to expose gaps in data availability.

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